DOCUMENT RESUME

ED 180 150 EC 121 999

AUTHOR Schmitt, Terry Lyndell
TITLE Early Experience and Spatial Functioning in the Blind.
INSTITUTION California Univ., Riverside.
SPONS AGENCY Bureau of Education for the Handicapped (DHEW/OE), Washington, D.C.
PUB DATE Jun 78
GRANT G007604392
NOTE 200p.; Ph.D. Dissertation, California University

EDRS PRICE MF01/PC08 Plus Postage.
DESCRIPTORS *Adventitiously Handicapped; *Blind; *Congenitally Handicapped; *Developmental Stages; *Performance Factors; Psychomotor Skills; Space Orientation; Tactual Perception; Task Performance; *Visual Learning; *Visually Handicapped; Visual Stimuli

ABSTRACT

A review of the literature on the spatial functioning of the blind, the results of a questionnaire of 75 sighted college students and their parents, and results of a study of 87 blind and seeing adults' performance on three spatial tasks are presented. The review suggested that adventitiously blind individuals perform better than congenitally blind individuals on tasks where the stimuli were complex, familiar and/or appended within arm's length of the body. Results of the questionnaire were used to predict several performance measures from the three spatial tasks. The findings indicated that tactual pattern discrimination performance and tactual path learning performance were primarily predicted by the degree of early visual experience, whereas locomotor path performance was primarily predicted by the degree of perceptual motor experience. The preliminary and final questionnaires and a table of correlations between all dependent variables are appended. (Author/PHR)

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University of California

Riverside

Early Experience and Spatial Functioning in the Blind

A Dissertation submitted in partial satisfaction

of the requirements for the degree of

Doctor of Philosophy

in

Psychology

by

Terry Lyndell Schmitt

June, 1978

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EC121999

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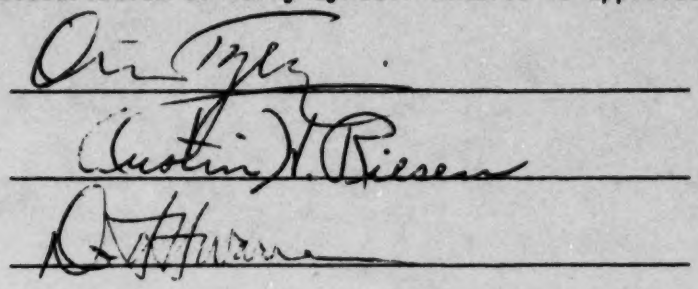

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June, 1978

ACKNOWLEDGEMENTS

To Juli, who shared my excitement and frustrations and whose love and understanding were unlimited, I express my deepest affection.

I gratefully acknowledge the guidance, instruction and support offered so unselfishly by my advisor, Dr. David H. Warren, throughout my graduate training. I am indebted to my other professors, especially Dr. Ovid Tzeng, who continually provided me with opportunities and encouragement to develop my academic and research skills. I also acknowledge a very special friend and mentor, Dr. Michael Sieck, who continually supported and encouraged me. My office partner, fellow graduate student, and friend, Tom Patterson, was always a source of inspiration and support, as well as a confederate in a sometimes mischievous conspiracy to maintain sanity and survive graduate school. We won.

The research reported in this dissertation could not have been completed without the cooperation and assistance of numerous individuals and agencies working with the visually impaired. Dr. Phil Hatlen was instrumental in directing me to these individuals and agencies, who were exceedingly generous with their time, knowledge, and facilities. Scott Cain was an excellent research assistant and co-worker. The research was supported by grant #G007604392 from the Bureau of Education for the Handicapped, U.S. Office of Education, to the author and his advisor.

ABSTRACT OF THE DISSERTATION

Early Experience and Spatial Functioning in the Blind

by

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Doctor of Philosophy, Graduate Program in Psychology

University of California, Riverside, June, 1978

Professor David H. Warren, Chairman

A review of the literature on spatial functioning of the blind suggested a distinct advantage for adventitiously blind individuals compared to congenitally blind individuals on some tasks but not others. Specifically, superior performance by adventitiously blind subjects relative to congenitally blind subjects appeared on tasks where the stimuli were complex, familiar and/or apprehended within arm's length of the body, but not on tasks where the stimuli were relatively simple, novel and/or apprehended only through locomotion. The experiments in this dissertation tested the hypothesized effect of task complexity while assuring novelty of all stimuli in 2 near-space tasks (tactual pattern discrimination and tactual path learning) and a far-space task (locomotor path task).

The literature review also revealed two hypothesized developmental explanations for the observed deficits in the spatial functioning

of congenitally blind subjects relative to adventitiously blind subjects. One explanation emphasizes the role of the absence of a structured visual frame of reference during development, while the other emphasizes the lack of active perceptual-motor behavior during development that often accompanies blindness. The relative importance of these 2 kinds of experiences in the prediction of spatial performance was also studied in this dissertation project.

Specifically, a questionnaire was developed to assess the visual and perceptual-motor aspects of a person's early experience. The ability of these measures of early experience to predict several performance measures from the 3 spatial tasks noted above was then determined in a multiple regression analysis. The results indicated that tactual pattern discrimination performance and tactual path learning performance were primarily predicted by the degree of early visual experience, whereas locomotor path performance was primarily predicted by the degree of perceptual-motor experience.

These and other results were discussed in the context of current hypotheses about the development of spatial ability, especially in blind individuals. The value of the questionnaire measures in accounting for individual differences in spatial performance in the present research was emphasized and it was urged that the questionnaire approach be applied to other research problems.

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INTRODUCTION

The importance of early experience to the development of adequate behavior patterns has been emphasized by several authors (Hebb, 1949; Vernon, 1970; White, 1971; White & Watts, 1973; Yarrow, Rubenstein & Pederson, 1975). The increased interest in the role of the environment during development has led to studies of the sensory experience of organisms. These studies have primarily used animals as subjects since ethical considerations make it impossible to tamper with the environment of humans. There is, however, a large body of literature which has investigated the effects of various handicaps in humans, such as deafness and blindness, which limit the sensory experience of their victims.

Much of the work with the blind has concentrated on spatial behavior. It is commonly accepted that the everyday spatial functioning of the blind is not as adequate as that of the sighted, although there has been very little research that compares blind with sighted subjects in real-life situations. Rather, the research literature has concentrated on laboratory tasks such as tactual form discrimination, maze-learning, tactual embedded figures and pattern replication. The bulk of the research supports the notion that the spatial abilities of the blind are indeed inferior to those of the sighted. However, most investigators have compared <u>blindfolded</u> sighted subjects with blind subjects on their tests of spatial functioning and it may be argued (Warren, 1977) that the more useful comparisons are those among blind groups with varying visual histories and between blind and sighted

performing with vision.

In total, the results are complex but suggest that sighted subjects and blind subjects with visual experience perform better than congenitally blind subjects on spatial tasks which are more difficult and involve only the area surrounding the body within arm's length, i.e. "near-space" (Warren, Anooshian & Bollinger, 1973). On the other hand, congenitally blind subjects show less disadvantage in locomotor, or "far-space" tasks. Thus, early vision appears to play an important role in the development of at least some aspects of spatial perception. Currently, there are two hypotheses regarding the effects of visual impairment on the spatial functioning of the blind. One hypothesis emphasizes the importance of the lack of a spatially structured visual frame of reference (Warren et al., 1973) and the second identifies the lack of general mobility and sensory-motor interaction with the environment which often accompanies visual impairment as the major factor leading to retarded spatial abilities in the blind (Jones, 1975).

The purpose of the present paper is to review the available data on the spatial functioning of the blind in near- and far-space as it relates to visual experience, to explore the two hypotheses offered to explain the effects of visual impairment on spatial functioning, and to describe a research project designed to test hypotheses generated from consideration of the above.

Near-space Performance

Sylvester (1913) was one of the first investigators to compare the spatial abilities of blind persons having different amounts of

visual experience. He compared congenitally, early (onset before age 3 yrs) and late (onset after age 3 yrs) blind adolescents on a form board task where subjects had to match solid forms with holes in a board. Both average time-per-trial and average number of errors indicated that the congenitally blind were worst, then the early blind, and the late blind were substantially better than the early blind. Sylvester attributed the superior performance of the late blind to visual imagery and suggested that even a well developed tactual spatial system could be enhanced by visual imagery made possible by early visual experience.

Worchel (1951) compared congenitally blind, adventitiously blind (onset between 1 and 11 years of age) and blindfolded sighted subjects on three different types of spatial tasks: form perception, mental combination of block forms, and locomotor-orientation. The sighted were better than the blind groups in all three tasks and the adventitiously blind were better than the congenitally blind in the first two tasks. However, as Juurmaa (1973) has pointed out, the forms used in the first task were very common (e.g., square, triangle and elipse) and therefore the advantage of the sighted and adventitiously blind may have been due to their greater familiarity with the stimuli rather than to a better developed system of spatial abilities. This interpretation is supported in the first task by the fact that Worchel's three groups of subjects performed equally well in the form perception task when a recognition response was required but were inferior when asked to draw or to give a verbal description of the test figure. All groups performed almost perfectly in the recognition condition, though, and the lack of differences was clearly due to a ceiling effect.

There were only two errors (by two congenitally blind Ss) in this condition in the entire experiment. Ewart and Carp (1963), however, also obtained equal performance by blind (light perception or less) and sighted in a tactile form discrimination task using the Worchel forms and a more difficult set of response choices which yielded a wider range of scores and avoided a ceiling effect. These results suggest that visual experience may be advantageous only when near-space tasks require perception of familiar objects or responses which normally depend upon vision such as drawing.

In Worchel's second task subjects felt the two parts of a familiar form (e.g., square, circle, triangle, ellipse), one part in each hand, then chose which of four forms corresponded to the combination of the two parts. The late blind were significantly better on this task and there was a significant positive correlation between the age of onset of blindness (range: 1-11 yrs) and performance within the late blind group.

Drever (1955) replicated Worchel's form combination task and found that the late blind (onset after age 4 yrs) group was superior to the early blind (onset before age 4 yrs). These results confirmed those of Worchel. In a second task subjects felt a pattern of pegs on a peg-board. The board was then rotated 180 degrees, after which the subject had to recreate the original pattern on the board. In this task early blind and sighted were equal in performance and both were worse than the late blind. Chronological age, IQ and length of blindness were found not to be related to the performance of these subjects. Drever concluded that there must be early spatial learning which occurs

in sighted children and allows those who later become blind to develop and utilize their tactual spatial abilities. Presumably the sighted performed worse because of the novelty of having to rely upon tactual cues alone and the early blind performed worse because they had not had the early learning. The early learning suggested by Drever involves the acquisition of spatial abilities which allows one to use tactual spatial information more effectively. The acquisition is dependent upon the presence of vision during development. Life-long spatial learning in the congenitally blind via their intact modalities cannot fully compensate for the developmental loss caused by blindness. Whether or not the blind child is capable of similar early learning using his functional modalities is a separate consideration and one which has important practical implications.

In a related experiment Cleaves & Royal (1976) studied the ability to perform mental spatial transformations of a learned maze in sighted, congenitally blind and late blind subjects. After the subject learned the maze to a criterion with the preferred hand, the maze was covered and the subject had to point to several locations on the maze in three different conditions. In one condition the pointing responses were made as if the maze were in its original orientation. In the others, the S had to imagine the maze rotated 180 degrees about a horizontal or vertical axis. In all orientation conditions, the late blind and sighted did not differ from one another, and both groups showed less error than the congenitally blind group. Performance was not significantly correlated with IQ or age for any group. Within the late blind group the correlation of performance with age at onset of blindness

was significant in a direction indicating that the longer a subject had vision before becoming blind the better his performance. This result is consonant with the suggestion that early vision is important to the development of adequate spatial abilities and implies that spatial ability may be a function of the amount of early visual experience.

The results of Worchel's mental combination task and Drever's replication of it could be explained by Juurma's familiarity heuristic, since the response forms were similar to those in the form perception task. In an experiment bearing on this issue, O'Connor and Hermelin (1975) compared congenitally blind and blindfolded sighted adolescents on a tactual shape discrimination task using very unfamiliar shapes. The performance of the two groups was equal. In a second experiment the subjects were required to identify a model hand (a familiar object) as left or right when it was presented in a variety of orientations. In this task the blindfolded sighted were superior to the blind. The authors interpreted these results as evidence that when a spatial judgment about an object is required, superior performance occurs by blindfolded sighted subjects because of the ease with which a visual code can be used for the object (i.e., how familiar the object is). In another study, Juurma and Suonio (1969) tested the hypothesis that optification (visual imagery of spatial input) during a block combination task like Worchel's aids sighted Ss only when the forms are visually familiar. They used three tasks: (1) replication of Worchel's second task where parts and wholes were visually familiar, (2) a similar task in which the wholes were familiar but not the parts, and (3) a

similar task in which parts and wholes were unfamiliar. Sighted subjects were superior in task 1 but equal in tasks 2 and 3 to the congenitally blind. Thus, their hypothesis that the sighted are advantaged only when visually familiar test objects are used was supported. Both the O'Connor and Hermelin (1975) and the Juurma and Suonio (1969) studies suggest that the familiarity of stimulus materials should be equal for sighted and blind groups in studies designed to assess their relative performance in spatial perception tasks. In the present research I attempted to create this equality by the use of random patterns.

The possibility that the adventitiously blind are also capable of using visual images of stimuli in tactual spatial tasks has not been directly tested. However, the intermediate performance by late blind subjects in Worchel's form replication, form description and form combination tasks and Drever's (1955) form combination task suggest that the late blind may be aided by visual imagery of the familiar forms. On the other hand, late blind subjects in the Cleaves and Royal study performed better when a fairly uncommon spatial array (a maze) was used. Thus, early visual experience may lead to a better general spatial ability to use visual images of stimuli. In any case, performance differences on tasks were unfamiliar stimuli are used are more likely to reflect differences in general spatial abilities than performance differences on tasks where common or familiar stimuli are used.

Studies of tactual maze learning in the blind also show that performance by the late blind is superior to that of the early blind.

Carr (1921) reported that Koch tested three blind subjects on a stylus maze and found that the two congenitally and totally blind subjects performed much worse, both in number of errors and in time to acquisition, than a blind subject who had some residual vision. The subject with residual vision performed similarly to sighted subjects. Although residual vision is confounded with early visual experience for this subject, Duncan (1934) showed that the present degree of vision is of much less importance to maze learning than the duration of early vision. Koch and Ufkess (1926) also tested blind subjects on a stylus maze and found reliable correlations indicating that those subjects who had more visual experience needed fewer trials and made fewer errors in learning the maze.

Knotts and Miles (1929) compared blind and sighted subjects on idential finger and stylus mazes and found that the blind were better than the sighted on both mazes. Within the blind group, they found that a subgroup of late blind subjects (onset after age 5 yrs) performed better than a subgroup of early blind subjects on both mazes. Similarly, Duncan (1934) found that subjects with a history of perfect vision learned a finger maze more easily (fewer errors) than subjects with a history of imperfect vision. Her data also indicate that the length of early vision was more predictive of performance than was the amount of residual vision, although no statistical analysis was available.

Berg and Worchel (1956) found mixed evidence for the importance of early visual experience in finger maze learning. They found no difference between congenitally and adventitiously blind (age of onset:

1 to 12 yrs; mean = 5.7 yrs) on a right angle U maze with 24 two-choice points. However, the late blind subjects were significantly better on an X maze with 10 two-choice points. These studies of maze learning suggest that visual experience may accompany a better ability to apprehend and use tactual spatial features in sighted and adventitiously blind individuals.

In summary, research on near-space performance on form boards (Sylvester, 1913), form discrimination tasks (Worchel, 1951; Ewart & Carp, 1963; O'Connor & Hermelin, 1975), mental manipulation of forms (Worchel, 1951; Drever, 1955; Cleaves & Royal, 1976; Juurmaa & Suonio, 1969), and maze learning (Carr, 1921; Koch & Urkess, 1926; Knotts & Miles, 1929; Duncan, 1934; Berg & Worchel, 1956) suggests that the early visual experiences of sighted and adventitiously blind subjects afford them some advantage relative to subjects with no prior visual experience. There is mixed evidence regarding whether or not this advantage is due to a better general spatial ability or to the ability to use visual images of familiar stimulus materials. Therefore, the use of unfamiliar stimulus materials was suggested for the study of general spatial ability in blind and sighted individuals.

Far-space Performance

The studies discussed above were primarily concerned with tactual spatial performance. While there are some inconsistent results (e.g., Berg & Worchel's U maze) the tendency is to find later blind subjects performing better in these tactual tasks than early blind subjects. As noted previously, Warren et al. (1973) found it useful to distinguish between these tactual, "near-space" tasks and "far-space" tasks that

involve locomotion and body orientation. An example of a far-space task can be found in Worchel's study. His third task required subjects to return to a starting point along the hypotenuse of a right triangle after being walked from the starting point along the two legs, or to return via the two legs after being walked along the hypotenuse. He found the blindfolded sighted group to be significantly better in this task, while the congenitally and adventitiously blind groups were equal. Within the adventitiously blind group, there was no relationship between the age of onset of blindness and performance, suggesting that visual experience is not a factor in this type of task.

In a study by Cratty (1967), congenitally blind subjects were better (veered less) at maintaining a straight line of walking than adventitiously blind subjects and the blind as a group were better than matched blindfolded sighted. In a subsequent study (Cratty, Peterson, Harris & Schoner, 1968) adventitously blind subjects were better than congenitally blind subjects in walking through a curved path. The discrepancy of these results can be explained on the basis of familiarity, as discussed later in this section.

In another task involving "far-space" perception, McReynolds and Worchel (1954) found that congenitally and adventitously blind subjects were also equal in their ability to orient to geographical directions and to indicate the relative directions of well-known places. There was again no significant relationship between the amount of visual experience and performance within the adventitiously blind group. These results indicate that the blind possess some representation of extended space, and that visual experience is apparently not necessary

for the development of this ability.

Juurmaa's (1973) use of a familiarity heuristic to explain differences in near-space performance by blind and sighted and by early and late blind can also be applied to far-space performance. Worchel's subjects traversed a right triangle, while the subjects in the Cratty et al. study walked a curved path of constant radius. Both tasks involve patterns with which sighted persons would be likely to have a great deal of visual familiarity. Thus, superior performance by the sighted, and to some extent the adventitiously blind could be due to their greater familiarity with the stimulus patterns. Support for this notion comes from a study by Juurmaa (1965), in which congenitally blind and blindfolded sighted subjects were walked along a complicated path (less familiar than two legs of a right triangle) and then requested to return straight to the starting point. The blind were significantly better than the blindfolded sighted. This result suggests that perhaps the blindfolded sighted subjects in Worchel's study performed better because they had more experience with right triangles.

If the results of Cratty (1967) and Cratty et al. (1968) are to be accounted for by a familiarity heuristic, we must assume that the curved path was more familiar than the straight one since subjects with some visual experience performed better on the curved task. There is no reason to believe that a curved path is any more visually familiar than a straight one, especially considering the construction of our streets and sidewalks. However, it is reasonable to assume that all subjects would have a great deal of experience walking in straight lines and very little experience walking the radii of large circles. On the

other hand, the sighted and adventitiously blind subjects would be likely to have had more experience with circles since circles are more often seen than walked. Thus, superior performance by the congenitally blind on the straight path might be due to a combination of the lack of a familiarity advantage for the adventitiously blind and sighted groups and greater experience in walking without vision for the congenitally blind group. The superior performance by the adventitiously blind on the curved path, however, might well be explained by a greater familiarity with circular spatial arrays and the acquisition of the concept of a regular arc.

Warren et al. (1973) suggested that the important factor in these tasks might be the complexity or difficulty of the task. According to this suggestion, having had visual experience in one's life is advantageous only when the demands of the task are sufficiently great, as might be the case in the curved path task. However, Juurmaa (1965) found that congenitally blind subjects actually performed better on a complicated locomotor task than blindfolded sighted subjects. Thus, the role of task complexity in revealing the effect of early visual experience remains an unresolved issue. In the research described later in this paper, two levels of complexity were incorporated into the design of each task in order to test the hypothesis that there is an interaction between the presence or absence of early visual experience and task demands.

There is little evidence in these studies of far-space performance to suggest that individuals who have had visual experience are afforded any advantage in tasks requiring the apprehension of novel or unfamiliar

spatial information for the purposes of locomotion. If anything, they are better able to execute spatial patterns with which they have had extensive experience. However, non-visual experience appears to be equally important to the ability to execute familiar spatial patterns, since the congenitally blind were better at walking in a straight line, a pattern with which they presumably had a great deal of experience. The need for the use of unfamiliar stimulus patterns exists in the study of far-space ability just as it did in the study of near-space ability. For this reason random patterns were used for all spatial tasks in the present research project.

Spatial-perceptual Systems and Explanations of Deficits

The results of the form perception and finger maze studies almost always have found the early blind at a disadvantage. On the other hand, the studies of orientation and locomotion, i.e. far-space tasks, usually have found the early blind at least as good as the late blind. The fact that the congenitally blind are able to perform some far-space tasks as well as or better than the sighted and adventitiously blind suggests that there is a spatial perceptual-motor system which develops independently of visual experience. Although it is clear that this system serves the same function for the blind that the spatial systems of the sighted and adventitiously blind serve for them, there is very little data concerning the equivalence or non-equivalence of the systems in the various groups or whether the sighted have a non-visual spatial perceptual-motor system similar to that used by the blind.

It would seem beneficial at this time to discuss the concept of a "spatial-perceptual system" and how it relates to the present analysis.

Far-space tasks require the integration of sensory information about the body and environment, motor skills, and an internal spatial framework or reference system. The near-space tasks also involve these components of behavior. However, the two kinds of tasks differ in the modality of information input and in the response demands. The far-space tasks utilize primarily body kinesthetic information and locomotor responses, while the near-space tasks utilize primarily tactual and hand/arm kinesthetic information and verbal, matching, or manual reproduction responses. The common element in all tasks seems to be the internal spatial framework or reference system. The relevant issue for this analysis is whether there is a single spatial reference system for all tasks or separate spatial reference systems for the various types of tasks.

Gibson (1966) adopted a conceptualization of sensation and perception which was exhibited boldly in the title of his book "The senses considered as perceptual systems." According to this conceptualization, perception occurs as a consequence of the activity of perceptual systems which utilize the more traditionally known "sensory" and "motor" components of an organism to extract information about the internal or external environment. This information leads directly to perception. Gibson argues that many perceptual systems may extract redundant information leading to a single perception. For example, we can see, hear, smell and feel a fire. All of these together or any one alone lead to the perception of "fire." If we adopt this view of the perception of spatial relationships, we can conceive of a "spatial-perceptual system" which extracts spatial information from the environment via all the

traditional sensory modalities. This spatial-perceptual system acts as an integrating center to which all spatial information is referred for processing.

The notion of a single, underlying spatial system receives very little support from studies of the ability structure of sighted subjects performing various near- and far-space tasks. Juurmaa (1965, 1967, & 1973) studies a wide range of spatial tasks in blind and sighted adult subjects. He found that tactual (e.g., assembling a cube from parts) and locomotor (e.g., walking a complicated path) items loaded on separate factors for the sighted subjects and that visual-spatial items (e.g., identifying components from visual inspection of a complex form) formed a third, independent factor. Within the blind group, though, the tactual and locomotor items loaded on a common factor. This result could mean that the spatial ability structure of the blind is less differentiated, although they were at least as good as the sighted subjects on all tasks (of course, the blind did not perform the visual-space tasks). If lack of visual experience inhibits the differentiation of the spatial-perceptual system then the degree of differentiation should be correlated with the amount of early vision before blinding. Unfortunately, Juurmaa apparently combined congenitally and adventitiously blind in his factor analysis, and evidence of differentiation for the later blind individuals may have been masked by the scores from the early blind.

It may be hypothesized that there is a basic spatial-perceptual system in all individuals and that early vision acts to enhance only that aspect involved in near-space tactual functions. At the same

time, the spatial-perceptual system is adequate for far-space locomotor tasks and develops normally even in congenitally blind individuals. However, if there is a basic spatial-perceptual system which is highly developed even in the blind why is it useful only in far-space tasks? There are at least two possible answers. One is that the locomotor and body orientation systems may have direct access to the spatial-perceptual system whereas the tactual modalities do not. A second possibility is that the far-space tasks lend themselves to verbal mediation more readily than the near-space tasks and that the spatial-perceptual system is accessed verbally in these situations.

There have been at least two explanations proposed for the deficits in the spatial functioning of the blind. Warren (Warren et al., 1973; Warren and Kocon, 1974; Warren, in press) has advanced the hypothesis that early vision may serve to establish a more effectively organized spatial reference system than that which develops in the total absence of vision. According to Warren (in press), vision "not only provides the most consistent, reliable, and precise source of spatial information, but it also may serve an important organizational and interpretive function with respect to spatial cues received via the other modalities" (p. 43). Referring to the fact that the later blind often perform better in spatial tasks than the congenitally blind, Warren suggests that "a period of early vision produces a lasting advantage in intermodal organization for later blind people and, of course, for sighted people." This formulation emphasizes <u>intermodal organization</u> in people with early vision such that all sensory modalities have direct access to the spatial-perceptual system, and therefore there

is greater opportunity for intermodal comparison and utilization of information. Even when blindness occurs at some later time, the benefits of the early vision are not lost, since the remaining spatial modalities remain effectively integrated. The studies discussed above which showed late blind subjects superior to early blind subjects in various spatial tasks support this notion.

This hypothesis receives some support from studies of intermodal spatial organization in blind subjects. Warren and Pick (1970) had sighted and blind subjects of various ages localize either a sound source or their forefinger when the two locations were in conflict. The sighted subjects and the blind subjects with some residual vision showed significant age tends indicating that the auditory information becomes more important with age, both in being less influenced by proprioception and in exerting more influence over proprioception. There were no significant age trends in the totally blind subjects. Obviously, those visually impaired subjects with even a small visual capability developed an auditory-proprioceptive intermodal spatial system like that of the sighted, whereas the totally congenitally blind did not.

Fisher (1964) found no significant differences between blind and sighted adults in the precision of judging the azimuth locations of auditory and tactual targets. However, on a comparison task involving auditory and tactual locations, some of the blind subjects performed much worse than the sighted. A spatial-perceptual system with poor intermodality organization could account for the poor performance of the blind. The results of Warren and Pick (1970 and Fisher (1964) suggest that although the spatial-perceptual system of the blind

functions well within a single modality, multimodal functioning is impaired. Warren (in press) suggests that when vision is not present during development the integration of spatial input from other modalities is not as effective.

Jones (1975) has proposed another explanation for the deficits in the spatial functioning of the blind. In sighted children, the spatial system is facilitated by their active motor involvement with the environment. He suggested that motor activity (which is often developmentally retarded and greatly reduced in blind children) serves to organize spatial input from the various modalities by providing connections between the various sensory areas of the brain via the motor cortex. Reich (1970) has shown that motor experience in childhood is positively correlated with motor performance in adulthood for sighted subjects. To the extent that this adult motor performance depends upon a spatial-perceptual system we can speculate along with Jones (1975) that early motor experiences are also important to spatial perception. According to this reasoning vision does not provide the organizing medium for all spatial inputs but it does provide the information which initiates and confirms motor localizing responses (e.g., eye movements, reaching, locomoting). Evidence for the importance of motor responses in spatial judgements comes from studies by Platt and Warren (1972) and Jones and Kabanoff (1975) which showed that auditory localization was facilitated by eye movements toward the source of sound. Platt and Warren also found that a textured visual environment in conjunction with directionally appropriate eye movements facilitated the auditory localization responses (both eye movements and pointing) compared to the same localization

performed in the dark. Jones suggest that the lack of a visual environment in blind persons disrupts localizing responses such as these and that it is the retardation of motor activity and lack of localizing behavior which lead to spatial deficits.

The relationship between blindness and retardation of specific motor abilities has been reviewed extensively by Warren (1977). Generally, studies of early motor development in blind infants (Norris, Spaulding, & Brodie, 1957; Fraiberg, 1968; Adelson & Fraiberg, 1974) show selective lags which seem to be concentrated in areas related to reaching and self-initiated mobility (crawling and walking). This is precisely the kind of behavior retardation which Jones (1975) predicts will lead to inferior spatial abilities.

Unfortunately, there is much less information avialable on the motor and locomotor behavior of the blind from infancy to age 5. There are, on the other hand, numerous studies of these abilities in blind children aged 5 and older. Buell (1950) noted various areas of motor performance related to physical education where blind school children do not meet sighted norms. He attributed these lags to the children's failure to engage in sufficient physical activity before entering school, and he suggested that the lack of physical activity was probably due to a combination of blindness-related developmental lags and parental overprotection.

Juurmaa (1973) reports a study by Gomulicki (1961) in which he studied the development of tactual and locomotor maze learning in congenitally blind and blindfolded sighted subjects between the ages of 5 and 16. At age five, the blind children were worse in both tasks,

indicating that either the spatial-perceptual development or the motor development (or both) of these children at 5 years was delayed. A second result indicating that at the age of 16 the blind children were equal to the sighted children in these same tasks suggests that experience with the environment independent of vision is sufficient for the development of motor and spatial perception. These results suggest that vision may be important to the rate of development of these abilities although we cannot say whether it is visual experience per se or the greater amount of motor interaction with the environment which facilitates earlier development in sighted children.

The two explanations rely on similar conditions for the retardation of blind spatial functioning. They both focus on a lack of integration and development within the spatial-perceptual system due to the absence of a specific kind of experience. They differ in the kind of experience specified as the necessary condition for optimal spatial-perceptual development. Jones (1975) emphasizes motor involvement in spatial behavior whereas Warren emphasizes a visual frame of reference in conjunction with spatial behavior as the important aspect of experience. The two explanations are not entirely inconsistent. Visual and motor experience are usually highly correlated with one another. A person who is very active and mobile tends to have a rich and varied visual environment. Similarly, a person who lacks visual stimulation tends not to be motorically involved with objects that are not heard or touched.

However, from my own observations and those of personnel working in blind services, there appears to be a great deal of variability

within the blind and sighted groups in the amount and variety of motor activity. Sommers (1944) has described several maternal attitudes toward blind children including overprotection, in which there is a tendency to restrict the activity of the child, and denial, in which the mother denies that the child has any limitations at all and insists on high standards of achievement. The precise way in which these attitudes affect the motor activity of the child has not been determined, but it is likely that these and other factors affect the activity of both blind and sighted children. It seems reasonable that since visual and motor experience vary between individuals, they both may contribute to the development of spatial ability. However, there has been no study which attempted to measure the motor experience of individuals independent of visual and blind experience or to relate these measures to measures of spatial functioning.

The two explanations proposed to account for the development of the spatial-perceptual system lead to different predictions regarding the relationship between these experience variables and spatial functioning. The motor experience explanation predicts that within a group of people with varying amounts of visual experience (i.e., the adventitiously blind) the variance of spatial functioning should be accounted for primarily by measures of motor experience with little or no additional variance accounted for by visual experience measures. On the other hand, the early visual experience explanation predicts precisely the opposite.

The Research

The present research project was designed to assess the perceptual and motor experiences of blind and sighted subjects and to evaluate the

relationships between these variables and spatial functioning as measured by 3 experimental tasks. The primary objectives were to develop a questionnaire to assess perceptual and motor experiences and to use the questionnaire to study the correlational links between the obtained experience variables and indices of spatial functioning in blind subjects. A third and equally important objective was to clarify certain theoretical issues discussed above concerning the role of various kinds of experience in the development of spatial abilities. Fortunately, these objectives embody both theoretical and practical goals. For example, the issue of whether it is visual experience or motor experience which serves to organize the spatial-perceptual system has implication for theories of perceptual development, as well as for the design of educational and training programs for the blind.

The spatial functioning tasks. Most studies have used only one or two tests of spatial behavior, and where multiple tests have been used, they have tended to be quite similar tests (e.g., two types of finger mazes, or two form discrimination tests. A widely-cited exception is a study by Wrochel (1951), who used two tests of form perception and one of locomotor behavior with a common group of subjects. However, no information was given about the degree to which the levels of performance within subject were covariant across the tasks. This weakness in the literature is unfortunate, since it is typically not clear whether deficits in relatively complex tasks might be attributable to an inability to perform simpler components of the more complex behaviors. Warren (1977) has argued that a "hierarchical" research approach to spatial functioning is needed, in which abilities are studied at several levels.

The present research thus included tests of three different levels of spatial behavior: tactual pattern discrimination, tactual path learning, and locomotor path performance. (a) The tactual pattern discrimination task required same-different judgments to pairs of raised patterns. In addition to providing information about tactual discrimination, this task was designed to show whether differences in performance are due to sensitivity differences or to differences in response criterion placement. This is an issue that has been largely ignored in comparisons among various blind groups or between blind and sighted groups (Jones, 1975). (b) The tactual path learning task required subjects to learn simple and complex pathways within a defined framework. To date, much of the research bearing on the construction of mobility maps has concentrated on the discriminability of components such as textures, lines, and symbols (e.g., Berla', 1972; Berla' & Murr, 1975). There has been less work on the ability of blind subjects to learn spatial relationships from maps, although some work does exist along these lines (e.g., Leonard & Newman, 1970). As the use of tactual maps for mobility becomes more widespread, information about path learning abilities will become critical to the design of optimally complex maps. (c) The locomotor path task involved two parts. In one, locomotor performance was assessed using the paths learned in the tactual path learning task. The other part of the locomotor task involved the execution of novel paths.

Two additional issues are important and were considered in the design of the experimental tasks. One is the issue of task complexity. As noted earlier, relatively complex tasks tend to differentiate early

and later blind subjects more than do relatively simple or easy tasks (Warren et al., 1973). In the present research two levels of complexity were used in each of the three tasks. The second issue is that of familiarity. Juurmaa (1973) has argued convincingly that it is on tasks where the stimulus materials are visually familiar that the blindfolded sighted subject performs better than the blind subject. Thus the advantage is chiefly for specific materials, rather than a general advantage. Since the concern of the present research is with general abilities, non-familiar stimulus materials were used.

Visual history of subjects. As noted earlier, much of the available information about the role of early vision in the development of spatial behavior has come from studies that have compared early with late blind subjects, rather than from those that have made various blind-sighted comparisons. Nevertheless, the visual history factor has not been evaluated in a sufficiently detailed way to allow very specific statements to be made about the role of vision. In some studies, "early blind" has been taken to include up to at least five years of early vision (e.g., Knotts & Miles, 1929), while other studies have set the cutoff as low as two years (e.g., McReynolds & Worchel, 1954). The rule of thumb that many researchers use is the three-to-five age range, on the assumption that less than three to five years of visual experience would not be effective in producing lasting effects. Warren et al. (1973) have argued that this issue has been conceptually oversimplified. They suggest that there may be several developmental stages during which it is particularly advantageous to have vision available. One such stage occurs before the middle of the first year,

when manual behavior begins to be brought under visual control. Having vision during this period may confer a lasting advantage that would become expressed in certain tests of spatial behavior, particularly those involving manipulatory behaviors. A second important stage may occur in the 8 to 20 month range, when locomotor behavior is developing. Again, the availability of vision during this period may confer lasting advantages in certain areas of spatial behavior.

The present research used both congenitally and adventitiously blind subjects. It was hoped that the size of the adventitiously blind group would be large enough to allow a detailed analysis of visual history factors within the adventitiously blind group, but the availability of subjects made it necessary to combine the two blind groups for purposes of analyzing individual differences. Important visual history factors include duration of early vision, time since blinding and amount of residual vision. As noted earlier, duration of early vision has received extensive attention, although not in a sufficiently detailed manner. This variable was studied over a wide range in the present research.

The varialbe "time since blinding" has received far less attention, although there are indications in the literature that it is an important variable in some kinds of spatial behavior. Cratty (1967), for example, found that Ss who had been blind longer veered less in a straight line walking situation than Ss who had been blind for shorter periods. It is not surprising that this variable should be important -- sighted Ss who are newly blindfolded often perform poorly on tests of spatial ability, only to improve relatively rapidly upon

gaining some practice in the test situation. Such practice effects may extend over a period of years. As Warren et al. (1973) point out, though, the effect of this variable tends to work against the effect of the duration of early vision; i.e., the longer a period of early vision a person had, the relatively less time he has been blind. The duration of early vision variable apparently has a stronger effect on most areas of spatial functioning. For these reasons, the effect of this variable was minimized by ensuring that all subjects be blind at least 3 years prior to testing.

The amount of residual vision may also play an important role in spatial behavior. There are some indications that spatial behavior is facilitated by residual vision (e.g., Leonard, 1969; Pick, Klein, & Pick, 1966), although this issue is by no means clear in the literature. Although most studies have analyzed for the effect of residual vision only when substantially more than light perception (LP) is available, there are some indications that even very small amounts of LP may be facilitory. For example, Fraiberg (1968) observed that an infant with LP in one eye spent time holding his hand up to a light, producing shadow patterns on the eye. In the present study, the blind samples included only subjects with light perception or less.

Most of the research that has made blind-sighted comparisons has required the sighted Ss to perform with blindfolds, under the supposition that this procedure produces a valid comparison of non-visual abilities. This reasoning is almost certainly specious. On the one hand, to the extent that early (and continuing) vision allows visualization of stimulus materials, the blindfolded sighted S enjoys a

considerable advantage in having had vision all his life. Blindfolding does not necessarily produce a situation where the other modalities can be evaluated without the influence of vision. On the other hand, the blindfolded sighted S is in effect a newly blind person, one who has not had substantial experience in perceiving without the aid of vision. Most studies have not allowed very much warm-up experience, and therefore the performance level obtained from blindfolded sighted Ss may represent not a stable level but rather an arbitrary point taken from a growth curve.

The issue of the relative adequacy of spatial functioning in the blind and sighted is an important one, however. It makes some sense to compare blind with sighted people in conditions where they each have the maximal possible information available to them, i.e., where the sighted perform with vision and the blind perform with whatever residual visual function might be available. In the present research, two sighted control groups were used, one that performed with vision available throughout, and one that performed while blindfolded. The blind Ss were not blindfolded. The primary comparisons between blind and sighted were made using the sighted group performing with vision. The blindfolded sighted group was used primarily to compare to the sighted group with vision. Such comparisons should provide useful information about the degree to which blindfolding produces immediate deficits as well as about the degree to which visual function continues to be effective even under conditions of blindfolding.

Early experience. Although developmental psychologists over the past 25 years have become increasingly conscious of the importance of

early experience for the development of later behavior, the issue of early experience has not been effectively researched with human subjects. Because of ethical constraints, conclusions about the role of experience in human development are inferential ones, derived from work with animals. It is possible to study variation in human environments without experimentally manipulating the environment -- wide variations occur naturally, and important parameters may be recorded and related to later behaviors. The longitudinal research design is an expensive one, though, and effective longitudinal work has not been done with a primary focus on the role of early experience.

A less rigorous, but still viable alternative to longitudinal work with human subjects involves the attempt to reconstruct information about early experience and motor development. Depending as it does on human memory, the reconstruction approach involves certain risks. If sufficient care is taken, however, it may be possible to obtain useful information about early experience at much less investment than is required by the longitudinal design. One important phase of the present research was the design, validation, and use of an early experience questionnaire. It involved interviewing the subjects themselves, but more importantly, it involved parents and other persons who were able to provide information about aspects of the subjects' histories. The instrument had a dual focus, first on the physical-sensory characteristics of the environment and second on the development of the individual's perceptual-motor behaviors. In the first category, information was gathered about the physical environment (e.g., large house or small, single story or more, yard or not, etc.) and the

sensory environment (quantity and degree of variety of sensory stimulation, including that provided by people). In the perceptual-motor category, attempts were made to reconstruct not only the general motor development sequence (e.g., onset of walking, crawling, etc.), but also the degree to which the individual engaged his physical-sensory environment via active motor behavior.

The research, then, consisted of the development of a questionnaire to assess the past experiences of subjects and a subsequent study of the relationship between early experience and spatial functioning. Development of the early experience questionnaire will first be described, followed by an account of the spatial functioning study.

METHODS

Questionnaire Development

Subjects. Eighty-five potential subjects and their parents received the preliminary questionnaire. All were sighted and were sampled from the general college population. The potential subjects requested the material after hearing announcements about the project in introductory psychology courses on the Riverside campus of the University of California. Seventy-five subjects (88.2%) from this original sample returned both parts of the questionnaire. These subjects included 24 males and 51 females who were aged 18 to 31 years (mean = 21.0 years). After both the subject and parent parts of a questionnaire were returned, the subject received $5 compensation.

Materials. The preliminary questionnaire is reproduced in Appendix A. In total, the questionnaire yielded 301 items of information. Some items provided information about attributes of each subject, e.g., age and sex, but most were part of subscales formulated to measure some aspects of the subject's experience. Five of the subscales, social contact, environmental variety, physical activity, manipulative activity and sedentary activity, were applied to each of five age periods-- 0-2 years, 2-5 years, 5-10 years, 10-16 years, and the subject's current age. Two other subscales, health and adult stimulation, were applied to the first 4 age periods. The remaining seven subscales, sibling contact, type of birth, rate of development, educational level, self-rated mathematical ability, self-rated spatial skills, and travel experience, were directed more

toward the total experience of the individual and were relatively unrelated to specific age periods. Including repetitions of subscales at more than one age period, 40 subscales were examined for acceptable reliability as described below.

Analysis. The number of respondents was too small to allow a meaningful factor analysis of the items. However, each item was chosen with a specific subscale in mind. Therefore, reliability coefficients were calculated on the subscales in order to gain some information about the internal consistency and therefore the content validity of the subscales. It was assumed that content validity was high on theoretical grounds and that acceptable reliabilities would indicate that the sub-scales were actually measuring the intended content.

Item scores from subscales which included items that had been estimated on different response scales, e.g., poor to excellent and 0 - 100%, were converted to z-scores before reliability tests were made. If all the items of a subscale were estimated in the same units, e.g., percent time or number of months, reliability tests were conducted on the raw scores. (Details of the scoring and scaling of all items can be obtained from the author.)

Cronbach's alpha or standardized alpha was computed on each subscale utilizing an SPSS reliability computer program (Nie & Hull, 1977) and the IBM-360 computer at the University of California at Riverside. Items were deleted when the deletion substantially increased the reliability of a subscale. The forty subscales are listed in Table I with the number of items in the scale, the number of

Table 1

Number of Items and Cronbach's α For Each Subscale From the Preliminary Early Experience Questionnaire

Subscale	Number of Items	α (n[a])	Subscale	Number of Items	α (n[a])
Social Contact (0-2yrs)	12	.23 (55)	Health (0-2)	4	.84 (60)
Social Contact (2-5yrs)	12	.34 (55)	Health (2-5)	4	.81 (60)
Social Contact (5-10yrs)	11	.45 (56)	Health (5-10)	4	.89 (60)
Social Contact (10-16yrs)	11	.44 (56)	Health (10-16)	4	.70 (60)
Social Contact (current)	6	.63 (73)	Adult Stimulation (0-2)	6	.50 (56)
Environmental Variety (0-2)	15	.57 (64)	Adult Stimulation (2-5)	6	.56 (56)
Environmental Variety (2-5)	16	.65 (64)	Adult Stimulation (5-10)	6	.61 (56)
Environmental Variety (5-10)	16	.73 (64)	Adult Stimulation (10-16)	6	.54 (56)
Environmental Variety (10-16)	16	.79 (64)	Sedentary Activities (0-2)	5	.22 (68)
Environmental Variety(current)	6	.50 (74)	Sedentary Activities (2-5)	6	.62 (68)
Physical Activity (0-2)	13	.64 (65)	Sedentary Activities (5-10)	6	.78 (68)
Physical Activity (2-5)	10	.62 (65)	Sedentary Activities (10-16)	6	.80 (58)
Physical Activity (5-10)	12	.74 (65)	Sedentary Activities(current)	7	.57 (74)
Physical Activity (10-16)	12	.72 (65)	Older Sibling Contact	3	.82 (69)

Table 1 (continued)

Subscale	Number of Items	α (n[a])	Subscale	Number of Items	α (n[a])
Physical Activity(current)	14	.69 (75)	Birth Status	3	.50 (75)
Manipulative Activity (0-2)	4	.11 (67)	Rate of Development	5	.51 (69)
Manipulative Activity (2-5)	4	.24 (67)	Educational Level	3	.88 (67)
Manipulative Activity (5-10)	4	.51 (67)	Math Ability	3	.87 (67)
Manipulative Activity (10-16)	4	.62 (67)	Spatial Skill	3	.73 (67)
Manipulative Activity (current)	5	.25 (75)	Travel Experience	4	.63 (67)

[a]n is the number of responses used in the computation of α

responses used in computing alpha, and Cronbach's alpha.

Subscales with reliabilities equal to or above .50 were retained and used in the spatial functioning study. Nunnally (1967) recommends that reliabilities of this magnitude are acceptable for research purposes in the initial stages of scale development. Thirty-two of the initial 40 subscales had acceptable reliabilities and were included in the final questionnaire along with several other items. A change was incorporated into the final questionnaire after several respondents on the preliminary questionnaire indicated difficulty understanding the concept of percent. Instead of estimating the percent of time in an average week that an activity occurred, respondents in the spatial functioning study estimated the number of hours in an average week that the activity occurred. The final form of the questionnaire is reproduced in Appendix B and will therefore not be described in further detail.

Spatial Functioning Study

Subjects. A total of 87 subjects were used in the study, although complete data were not obtained from all. For example, parent questionnaires were not received for 10 subjects and 3 subjects did not return for the second testing session. However, data from every subject were used in at least some of the analyses. Four groups of subjects were used. Sighted subjects (n = 20) with normal or corrected to normal vision performed all tasks using their vision. There were 10 males and 10 females in this group over an age range of 16 to 33 years (mean = 23.7 years). The blindfolded sighted group (n = 20) also consisted of 10 males and 10 females who ranged in age from 18 to 33 years

(mean = 22.1 years). Congenitally blind subjects (n = 21) with no other handicaps included 10 males and 11 females ranging in age from 19 to 31 years (mean = 24.1 years). Seventeen male and 9 female adventitiously blind subjects 18 to 36 years of age (mean = 26.1 years) comprised the fourth group of subjects. Duration of vision for this group ranged from 6 months to 29 years (mean = 12.3 years). All adventitiously blind subjects had been blind for at least 3 years.

The blind subjects were contacted through rehabilitation counselors and blind service centers in the San Francisco Bay area. The research project was described to the counselors, who then distributed at their discretion copies of the project description to their blind clients. If the client wanted more information about the project, the counselor put him in contact with the experimenter. Names of potential subjects were also provided by other subjects. Sighted and blindfolded sighted subjects responded to a local newspaper advertisement in the Riverside area. Upon completion of the second of 2 testing sessions, each subject received $15 compensation.

General procedure. The overall format of the study will be described here, while test materials and procedures for the individual spatial tasks will be described later.

After a subject indicated a willingness to participate in the study, the first of two testing sessions was conducted in the subject's home or in a quiet room at one of the testing locations. Subjects were tested individually. The overall procedure was explained to the subject and he or she signed a consent form. The subject then responded to the subject questionnaire which was verbally administered by the

experimenter. A parent's address was obtained during this period and part 2 of the questionnaire was later mailed to the parent(s). In this first session, the subject was also tested on the tactual pattern discrimination task and the Wechsler Adult Intelligence Scale (WAIS: Wechsler, 1955). Blind subjects were given only the verbal subscales of the WAIS while sighted subjects completed the entire scale. In total, the session required between 1 1/2 and 2 1/2 hours for completion.

The second testing session was conducted at one of six locations in California--an auditorium at the Orientation Center for the Blind in Albany, an auditorium at the Lions Blind Center in Oakland, a large classroom at California State University at San Francisco, an outdoor parking area at the Living Skills Center for the Blind in San Pablo, an outdoor patio at the University of California at Riverside, and an empty warehouse at the Center for Independent Living in Berkeley. During the second session the subject was tested on the tactual map learning tasks, the locomotor path tasks and the Stanford-Kohs Block Design test for the Blind (Suinn and Dauterman, 1966). The session was ended with a short informal interview in which the subject was questioned regarding his or her strategies on the tasks and on everyday spatial problems such as learning and remembering the layout of a town or building. The interview was tape-recorded. Upon completion of the second session the subject received $15 compensation.

Tactual pattern discrimination task. Two-dimensional patterns were designed in the following way. An 8x8 cm matrix of 16 2x2 cm elements was the beginning of each pattern. Six of the 12 peripheral

elements were randomly eliminated so that a pattern consisting of the original 4 central elements plus six of the original 12 peripheral elements was formed. The only constraining requirement was that each element included in the pattern have at least one of its 4 borders in common with another element. This procedure was repeated until 20 unique patterns were designed. With each pattern used in two pairs, these 20 patterns could be made into 20 unique pairs. In 10 pairs, the patterns shared 0 or 1 peripheral elements in common and were said to constitute a "simple" discrimination pair, and in the other 10 pairs, the patterns shared 4 or 5 peripheral elements in common and were said to constitute a "complex" discrimination pair. Each pattern occurred in one simple and one complex pair.

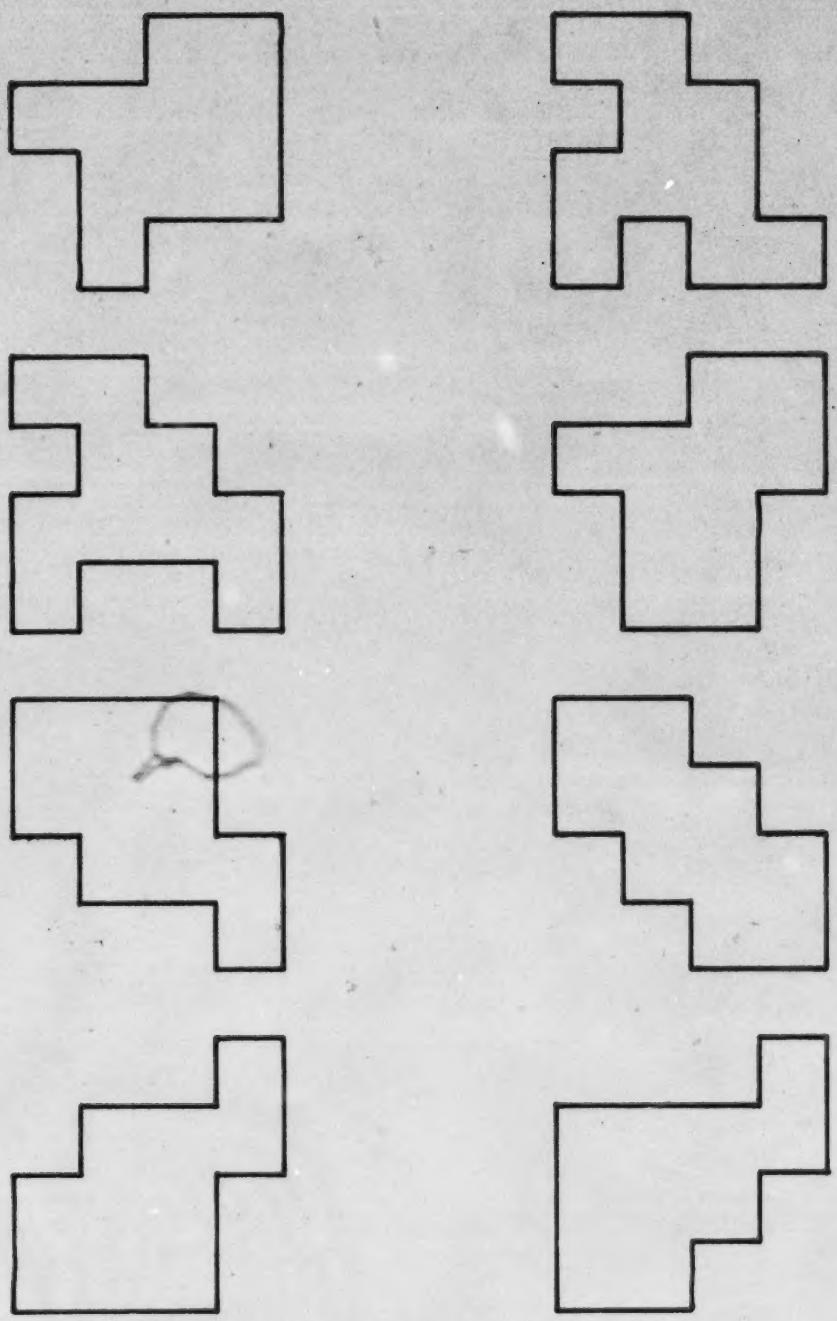
In a pilot study, 10 blindfolded sighted subjects were asked to make same/different judgements on 2 presentations of each discrimination pair (with position counterbalanced) randomly presented with 2 presentations of each pattern paired with itself. Thus, there were 80 trials on which a subject examined pairs of patterns presented side by side in front of him. Using the preferred hand, he first examined the pattern nearest that hand for 4 seconds and then the other pattern for a maximum of 4 seconds. He was allowed up to 5 seconds after the end of his examination of the second pattern to state whether the patterns were "same" or "different." It was emphasized that for 2 patterns to be the "same" they had to be the same shape and size and be in the same orientation. The next trial began 15 seconds after the subject's response. Half of the "same" trials were randomly designated as control trials for the simple discrimination task and

the remaining "same" trials served as controls for the complex discrimination task.

The results of the pilot study indicated that discrimination complexity, defined as the number of non-shared elements within a pair of patterns, was a useful concept. Both the number of "hits" ($t(df=9)=3.77$, $p < .01$) and the sensitivity measure d' ($t(df=9)=3.13$, $p < .01$) differentiated the complex from the simple discrimination pairs. However, some of the complex discriminations proved to be as easy as the simple discriminations and some of the simple discriminations were as difficult as the complex discriminations. In order to ensure a clear distinction between simple and complex discrimination pairs in the spatial functioning study, a subset of 8 patterns from the original 20 was chosen consisting of 4 clearly simple discrimination pairs and 4 clearly complex discrimination pairs. These eight patterns are shown in Fig. 1. The stimuli were cut from 1/8" masonite and mounted in the middle of 10 x 10 cm square pieces of 1/8" masonite.

In the actual spatial functioning study, the subject was introduced to the task and instructed with practice stimuli until the procedure was clearly understood. The stimulus pairs were presented as in the pilot study and a "same" or "different" response was recorded on each trial. The 4 "simple", 4 "complex" and 8 "same" pairs were randomly arranged to form a block of 16 trials which included a complete set of paired stimuli. Five such blocks were randomly ordered so that a total of 80 trials was presented to each subject. Same and different trials occurred with equal probability (.5). Half of the "same" trials were designated as control trials for the simple

Figure 1. Tactual pattern discrimination stimuli. The patterns were paired and presented to subjects in simple (e.g., top 2 patterns) and complex (e.g., bottom 2 patterns) discrimination trials.



discrimination task and the remaining same trials served as control trials for the complex discrimination task. After 40 trials, a 2 min rest occurred.

Hit and false alarm rates were determined for each subject for both the simple and complex discrimination tasks. A sensitivity measure (d') and a response threshold measure (β) were determined (Freeman, 1973) from the signal detection data.

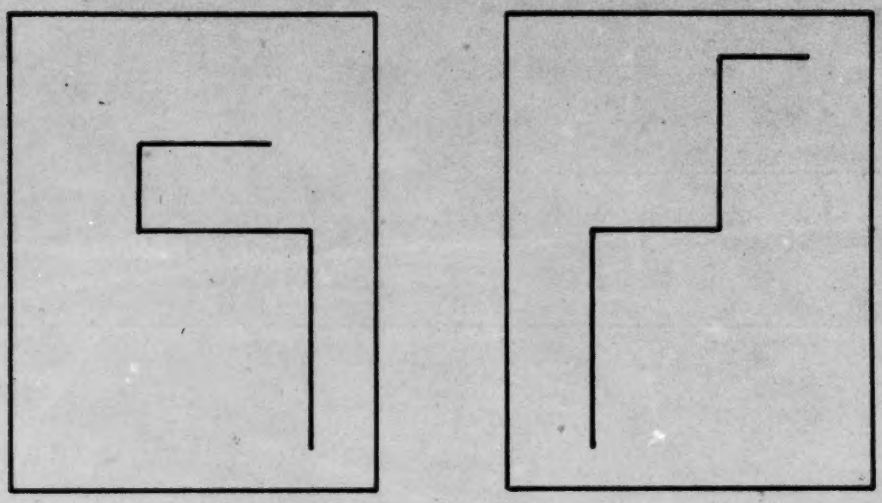
Task complexity (simple vs. complex) and groups (sighted, blindfolded sighted, congenitally blind and adventitiously blind) were the primary independent variables in this 2 x 4 split-plot factorial design (SPF4.2: Kirk, 1968) with repeated measures on the complexity variable.

Tactual path learning and locomotor path tasks. The stimulus materials and procedures for these tasks were similar and will therefore be presented together. Each of 4 path stimuli was 14 inches (34.40 cm) in length and had either 4 or 7 segments and either 3 or 6 turns. Each of 2 simple paths had 4 segments and 3 turns and each of 2 complex paths had 7 segments and 6 turns (see Fig. 2). Path stimuli for the tactual path learning task were cut from 3/16 inch Plexiglas and mounted on a board surrounded by a 3/16" raised border. Path stimuli for the locomotor path task were memorized by the experimenter who led the subject over the paths.

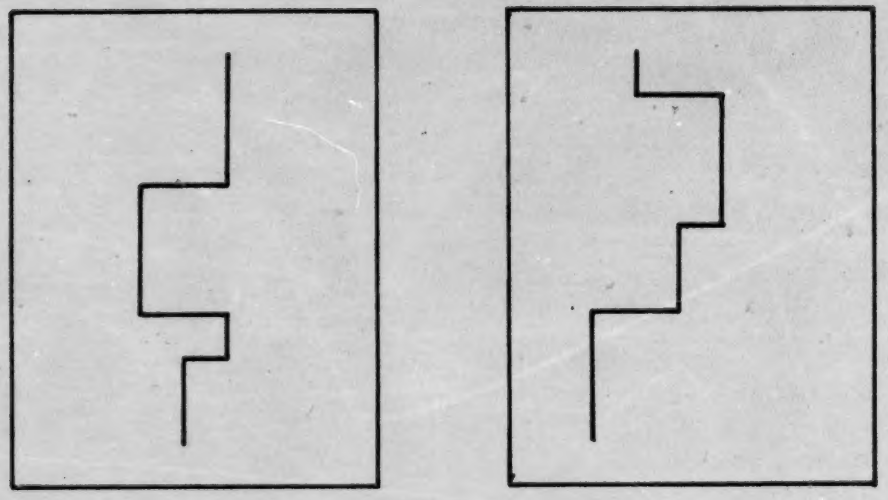
The nature of the tasks was such that a familiar locomotor path task always followed the tactual path learning task in which the familiar path stimulus was learned. On the other hand, the novel locomotor path task could occur at any time, since prior tactual

Figure 2. Path stimuli. The stimuli on the left were used in the tactual path learning task and the familiar locomotor path task. The stimuli on the right were used in the novel locomotor path task. (Scale: 1 in. = 4 in. for tactual stimuli; 1 in. = 8 ft. for locomotor stimuli.)

SIMPLE PATHS



COMPLEX PATHS



familiarization with these paths was not given. The order in which the path tasks were performed was counterbalanced so that a subject performed both novel locomotor or both familiar locomotor tasks first (and therefore a locomotor or a tactual task first). Within each novelty condition, a subject first performed either the simple or the complex task. Thus, there were 4 orders used in the experiment. In order 1, subjects first learned the simple tactual path followed by a locomotor task of the same simple path which was now familiar. The complex tactual path learning task and the familiar-complex locomotor path task followed with the novel locomotor path tasks (first simple, then complex) occurring last. In order 2, the two novel locomotor path tasks occurred first, followed by the tactual path learning and familiar locomotor tasks. Again, the simple version of each task occurred before the complex version. Order of tasks in order 3 was comparable to that in order 1, except that the complex version of each task occurred before the simple version. Similarly, order 4 was comparable to order 2 except that the complex version of each task occurred before the simple version.

Prior to the beginning of the first task, the subject was led to an area just in front of the table used for the tactual path learning task. The area was 17 x 22 ft and was surrounded by a rope about 3 ft above the ground. The subject entered the area and, following the rope, walked around the perimeter in order to experience the overall size of the area.

On the tactual path learning task a subject was given 30 seconds to explore the path stimulus with both hands. The exploration began

when the subject's hands were directed to the end of the path nearest him and he was told that this was the starting point of the path. On the first trial of each task, his finger was moved by the experimenter over the entire path, and both the starting and ending points of the path were emphasized. After the exploration period the subject was given a response board which was the same size as the stimulus board and which had a raised border similar to the border on the stimulus board. However, it had no raised path on it. The forefinger of the subject's preferred hand was placed on the response board at a point corresponding to the starting point of the path and he was asked to move the finger in a path like the one he had just explored. The subject was encouraged to use any method, including the use of the other hand, to help guide his hand over the path. He was allowed up to 1 minute to reproduce the path in this manner. The experimenter recorded the movement of the subject's forefinger on paper. Each trial consisted of a 30 second exploration period and a 1 minute reproduction period. Criterion for learning was defined as 2 reproductions which were within 3/4 inch of the original path.

Following a tactual path learning task, the subject was guided to the roped area for the familiar locomotor path task. There he was led with his left hand grasping the right arm of the experimenter over a path of the same shape as the one he had just learned in the tactual path learning task. He was then led back to the starting point and attempted to walk the path unaided. His movements were recorded by the experimenter. After executing the path he was asked to return in a direct line to the location of the starting point.

This location was also recorded by the experimenter. This procedure was repeated 3 times for each locomotor path task. That is, the subject was led over the path, walked the path unaided, and returned to the starting point on 3 successive trials. In total the subject learned 2 tactual paths and walked 4 locomotor paths of which 2 were novel in shape and 2 were the same shape as the tactual paths.

The design of the tactual path learning experiment included group, task order, and complexity as independent variables in a 4x4x2 split-plot factorial design with repeated measures on the complexity variable (SPF44.2). The design of the locomotor path experiment included the above independent variables plus a 2-level path novelty manipulation (novel and familiar) in a 4x4x2x2 split-plot factorial design with repeated measures on the complexity and novelty variables (SPF44.22).

Subjects' performances in the path tasks were scored on several dependent variables. For each reproduction in the tactual path learning task, i.e., one from each trial, 4 dependent variables were measured. A rating of the similarity between the shape of the reproduction and the shape of the actual path was chosen as a measure of the degree to which the subject extracted the relative spatial information contained in the stimulus, i.e., irrespective of overall size. An area measure of error was defined as the total area between the reproduction and the actual path and was obtained by placing a grid with 1/2" squares over the two patterns, connecting the end points (the starting point was always common to both), and counting the number of squares separating the 2 paths. When half or more of a

square was included, it was counted as one. A second error variable, distance, was defined as the length of the reproduction path (measured to the nearest 1/4") minus 14 inches, the actual length of the path. Thus, underestimations of the length of a path were negative and overestimations were positive. The absolute distance error was also determined and was the fourth variable measured.

Inter-rater reliability on the similarity ratings was determined in a pilot study in which each of 5 subjects made 8 reproductions of a simple path and 8 reproductions of a complex path. Two raters judged the resulting 80 paths on a 0-9 rating scale. In rating similarity, the raters considered the relative lengths of the segments, the number and appropriateness of the turns, and the addition or deletion of path elements as well as the overall form. A Pearson correlation between the 2 sets of ratings was .83, indicating a high inter-rater reliability.

For the analyses, two means were averaged from each of these dependent measures. An overall mean value for each variable was averaged across all learning trials for each subject. In addition, mean values from the last 2 learning trials were taken as measures of the final level of performance achieved by the subject. Finally, the number of trials to criterion was determined for each subject. If criterion was not reached within 10 trials, 2 was added to that number and the subject received a maximum score of 12. Thus, there were 9 dependent variables measured for each subject on the simple and complex paths in the tactual path learning task.

The same 4 variables, similarity, area, distance and absolute

distance, were measured on each of the 3 trials for each path in the locomotor path task. A fifth variable, starting point, was the distance between the actual starting point and the point which the subject indicated as the starting point at the end of each trial. These measures were averaged over the 3 trials for each path to obtain mean scores. Thus, there were 5 dependent measures for each subject on each of the 4 locomotor paths.

Measures of intermodality transfer were computed as the difference between a subject's performance on the novel and familiar paths within each complexity condition. Transfer scores obtained in this way were meaningful for all dependent variables except the distance variable, which, it was thought, would yield difference scores difficult to interpret due to variation in sign. Four transfer socres, then, were determined for each subject on the simple locomotor path and 4 on the complex locomotor path.

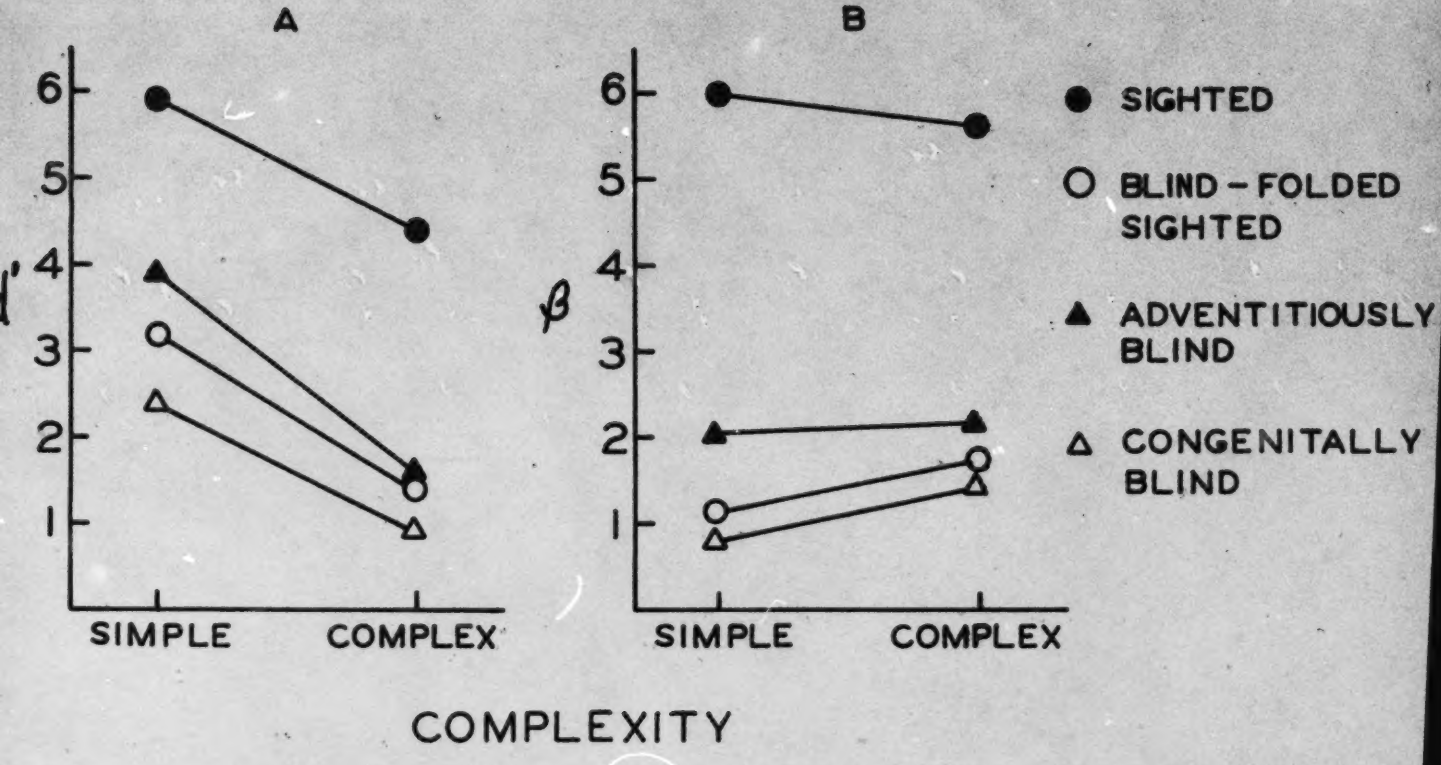
RESULTS: ANALYSIS OF VARIANCE

Tactual Pattern Discrimination Task

The mean sensitivity (d') to pattern differences for each group is plotted as a function of complexity in Figure 3a. The analysis of variance on this dependent measure indicated a significant group effect, $F(3,83)=44.28$, $p < .001$, and complexity effect, $F(1,83)=148.83$, $p < .001$, but no interaction between the two factors. Analysis of group differences by the Neuman-Keuls procedure indicated that the sighted had higher sensitivity than all other groups ($p < .01$ in all cases) and that the adventitiously blind were more sensitive than the congenitally blind ($p < .05$). The blindfolded sighted were not significantly different from either blind group. This is a classic pattern of results in studies of tactual discrimination. The adventitiously blind often perform better than congenitally blind, and the blindfolded sighted perform at an intermediate level. The main effect of complexity indicated that sensitivity to differences in the complex discriminations was lower than that for the simple discriminations, as would be expected.

The mean response threshold (β) is shown for each group as a function of complexity in Figure 3b. The analysis of variance revealed a significant group effect, $F(3,83)=21.58$, $p < .001$, but no effect of complexity ($F < 1.0$) or interaction of group and complexity ($F < 1.0$). Neuman-Keuls analysis of the differences between group means indicated that the sighted employed higher response criteria than the other 3 groups ($P < .01$ in all cases). The remaining groups

Figure 3. Mean d' (A) and β (B) for each group as a function of task complexity in the tactual pattern discrimination task. Significant effects of group on d' and β and of complexity on d' were present.


A
B
6
5
4
3
2
1
d'
β
SIMPLE
COMPLEX
SIGHTED
BLIND - FOLDED SIGHTED
ADVENTITIOUSLY BLIND
CONGENITALLY BLIND
COMPLEXITY

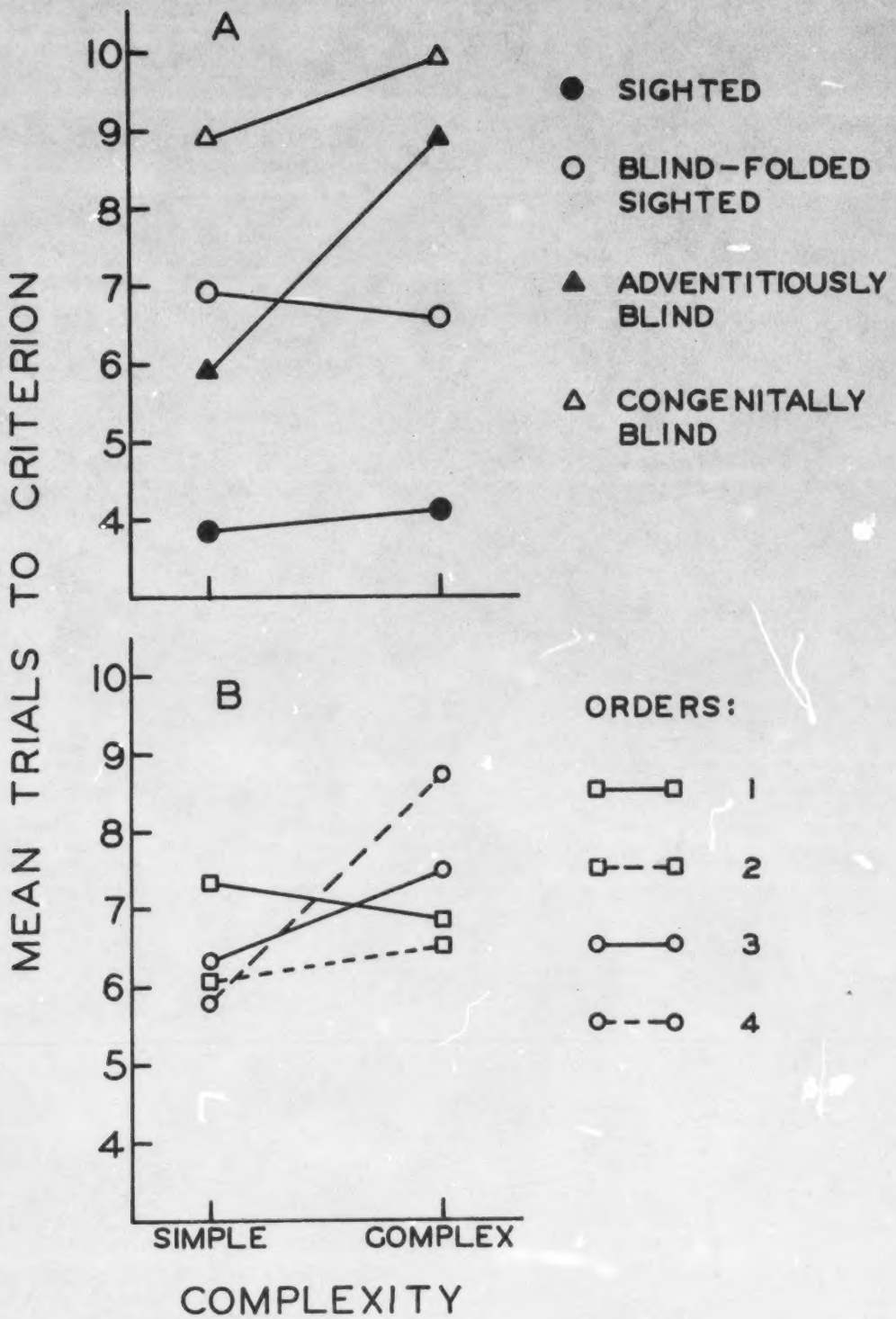
did not differ significantly from each other.

Tactual Path Learning Task

Each dependent measure was subjected to a 3-way analysis of variance with group and order evaluated as between-subject effects and complexity as a within-subjects effect.

Trials to criterion. The mean number of trials to reach criterion for each group is given in Fig. 4a for both complexity conditions. A significant effect of the interaction between group and complexity conditions was found $F(3,68)=4.27$, $p < .01$, as well as significant group, $F(3,68)=17.38$, $p < .001$, and complexity, $F(1,68)=7.81$, $p < .01$, main effects. Simple main effects of complexity within each group revealed that the adventitiously blind group required more trials to reach criterion in the complex condition than in the simple condition, $F(1,68)=18.41$, $p < .001$. Similarly, the congenitally blind, $F(1,68)=2.05$, $p > .10$, and the blindfolded sighted ($F < 1.0$) required statistically equal numbers of trials to reach criterion in the simple and complex conditions. The simple main effects of group were significant under both simple, $F(1,68)=33.81$, $p < .001$, and complex, $F(1,68)=50.13$, $p < .001$, conditions. A Neuman-Keuls analysis of the differences between group means on the simple task revealed that the sighted performed better than the adventitiously blind ($p < .05$), whose performance was equal to that of the blindfolded sighted, and that the congenitally blind performed worst of all ($p < .05$). On the complex task, the two blind groups were not significantly different from each other and both were worse than the blindfolded sighted ($p < .05$). The sighted

Figure 4. (A) Mean trials to criterion for each group as a function of task complexity in the tactual path learning task. Significant group, complexity, and group x complexity interaction effects were present. (B) A significant order x complexity interaction effect is illustrated in this graph of mean trials to criterion for each order as a function of task complexity.


A
B
10
9
8
7
6
5
4
MEAN TRIALS TO CRITERION
SIGHTED
BLIND-FOLDED SIGHTED
ADVENTITIOUSLY BLIND
CONGENITALLY BLIND
ORDERS:
1
2
3
4
SIMPLE
COMPLEX
COMPLEXITY

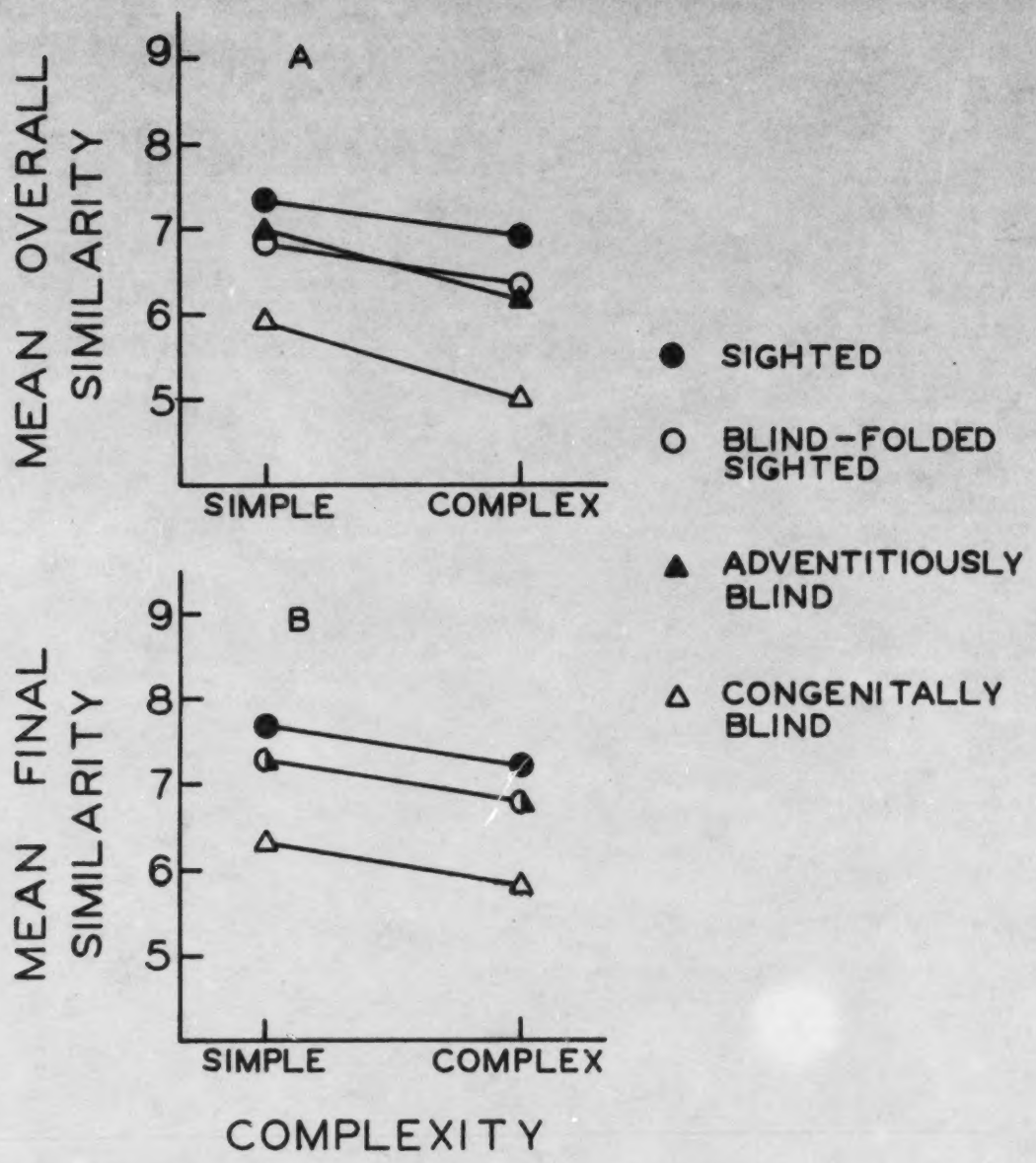
subjects were again superior to all other groups ($p < .01$ in all cases).

A significant interaction between complexity and order, $F(3,68) = 3.91$, $p < .05$, is graphed in Figure 4b. An analysis of the simple main effects of complexity at the order conditions indicated that when the complex path was learned first (Order 4), significantly more trials were required to learn it than to learn the simple path, $F(1,68) = 17.20$, $p < .001$), which was learned second. This same trend was evident in Order 3, in which the complex path was learned first, but was not significant, $F(1,68) = 2.95$, $p < .10$. On the other hand, the simple task was learned as quickly when it occurred first as when it occurred second (Orders 1 and 2). The simple main effect of order at the complex task was significant, $F(1,68) = 7.18$, $p < .01$.

Similarity. Significant group, $F(3,68) = 8.11$, $p < .001$, and complexity, $F(1,68) = 50.43$, $p < .001$, main effects were found for this dependent measure, which is graphed in Figure 5a for each group in each complexity condition. A Neuman-Keuls analysis of the differences between group means indicated that the sighted performed best ($p < .01$), the blindfolded sighted and the adventitiously blind were next and equal in performance and the congenitally blind scored significantly lower than the blindfolded sighted or adventitiously blind ($p < .05$). The main effect of complexity indicated that subjects' reproduced the simple path with greater accuracy than they reproduced the complex path.

Analysis of the mean of the similarity ratings on each subject's last 2 trials (see Fig. 5b) also yielded main effects of group, $F(3,68) = 5.96$, $p < .001$, and complexity, $F(1,68) = 17.43$, $p < .001$.

Figure 5. Mean overall similarity (A) and mean final similarity (B) for each group as a function of task complexity in the tactual path learning task. Significant main effects of group and complexity were found for both measures.

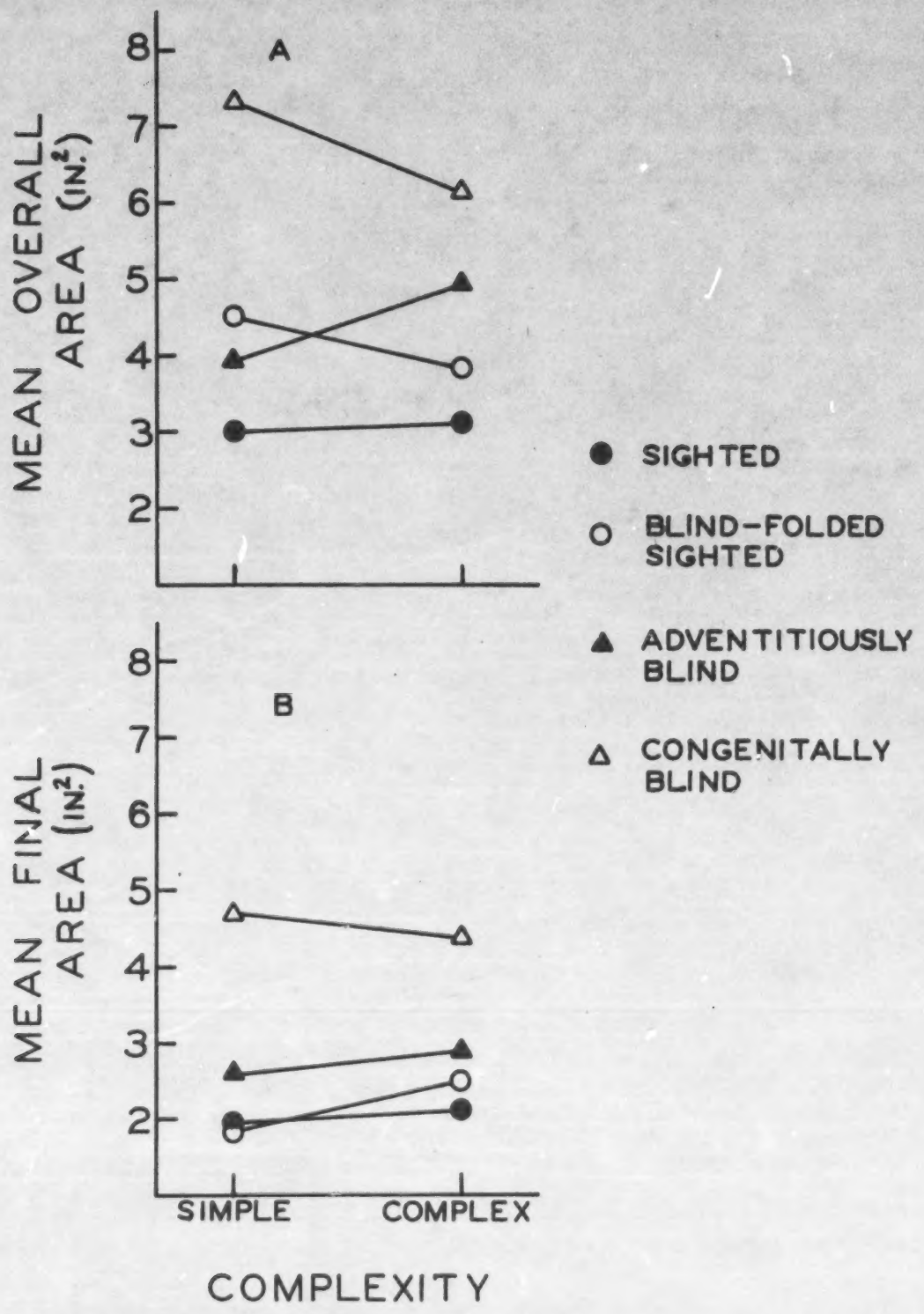

MEAN OVERALL SIMILARITY
9
8
7
6
5
A
SIMPLE
COMPLEX
MEAN FINAL SIMILARITY
9
8
7
6
5
B
SIMPLE
COMPLEX
COMPLEXITY
SIGHTED
BLIND-FOLDED SIGHTED
ADVENTITIOUSLY BLIND
CONGENITALLY BLIND

However, Neuman-Keuls analysis of group differences indicated that the sighted, blindfolded sighted and adventitiously blind groups were not significantly different from one another, and all received higher similarity ratings than the congenitally blind ($p < .05$).

Area. Analysis of variance on this error measure revealed a significant group effect, $F(3,68)=14.71$, $p < .001$, and a significant group x complexity interaction effect, $F(3,68)=2.77$, $p < .05$. The simple main effect of complexity was evaluated at each of 3 group conditions. The congenitally blind group made larger errors on the complex task than on the simple task, $F(1,68)=4.08$, $p < .05$, but the other 3 groups showed no increase in their errors on the complex path relative to the simple path (see Fig. 6a). The simple main effect of group at the complex path (where group differences were least) was significant, $F(1,68)=24.26$, $p < .001$. A Neuman-Keuls analysis of group differences within each level of complexity revealed that the congenitally blind made larger errors than all other groups on the simple path ($p < .01$) and on the complex path ($p < .05$). The adventitiously blind and the 2 sighted groups did not differ significantly on the simple path. However, the sighted made smaller errors than the adventitiously blind on the complex path ($p < .001$) but were not significantly different from the blindfolded sighted.

The mean area error score averaged from the last 2 trials was also determined for each subject and subjected to an analysis of variance. A significant group effect was found, $F(3,68)=8.05$, $p < .001$, but no other effects were statistically significant. Further analysis of group differences using the Neuman-Keuls procedure revealed that

Figure 6. Mean overall area (A) and mean final area (B) for each group as a function of task complexity in the tactual path learning task. There was a significant group effect on both measures and a significant group x complexity interaction effect on overall area.


A
B
MEAN OVERALL AREA (IN.²)
MEAN FINAL AREA (IN.²)
8
7
6
5
4
3
2
SIMPLE
COMPLEX
COMPLEXITY
SIGHTED
BLIND-FOLDED SIGHTED
ADVENTITIOUSLY BLIND
CONGENITALLY BLIND

the congenitally blind made larger errors than any of the other 3 groups ($p < .05$), which were not significantly different from one another (see Fig. 6b).

Distance. Analysis of variance on the distance error measure (see Fig. 7a) yielded no significant effects. Further, the overall mean was -.48 cm, indicating a slight overall tendency to underestimate the length of a tactual path. The distance error measure was also averaged for each subject's last two learning trials to obtain a mean final distance error score (see Fig. 7b). Analysis of this dependent measure indicated a significant effect of complexity, $F(1,68)=12.56$, $p < .001$, but no other effects. The length of the subjects' final 2 reproductions of simple paths was shorter than that of the complex paths, which were very accurately reproduced (14,13 in; 35.89 cm).

Absolute distance. The absolute values of the distance errors were also analyzed by analysis of variance and found to be subject to a significant group effect, $F(3,68)=3.70$, $p < .02$, but no other significant effects. The adventitiously blind, the blindfolded sighted, and the sighted appeared equivalent on this measure with the congenitally blind making larger errors (see Fig. 8a). However, multiple pairwise comparisons by the Neuman-Keuls analysis yielded no significant differences. The mean absolute distance error averaged from each subject's last 2 learning trials gave a similar pattern of results (see Fig. 8b), but the group effect was not significant, $F(3,68)=2.55$, $p < .07$.

In summary, the results of the analyses of variance on the

Figure 7. Mean overall distance (A) and final distance (B) for each group as a function of task complexity in the tactual path learning task. The only significant finding was a complexity effect on final distance.

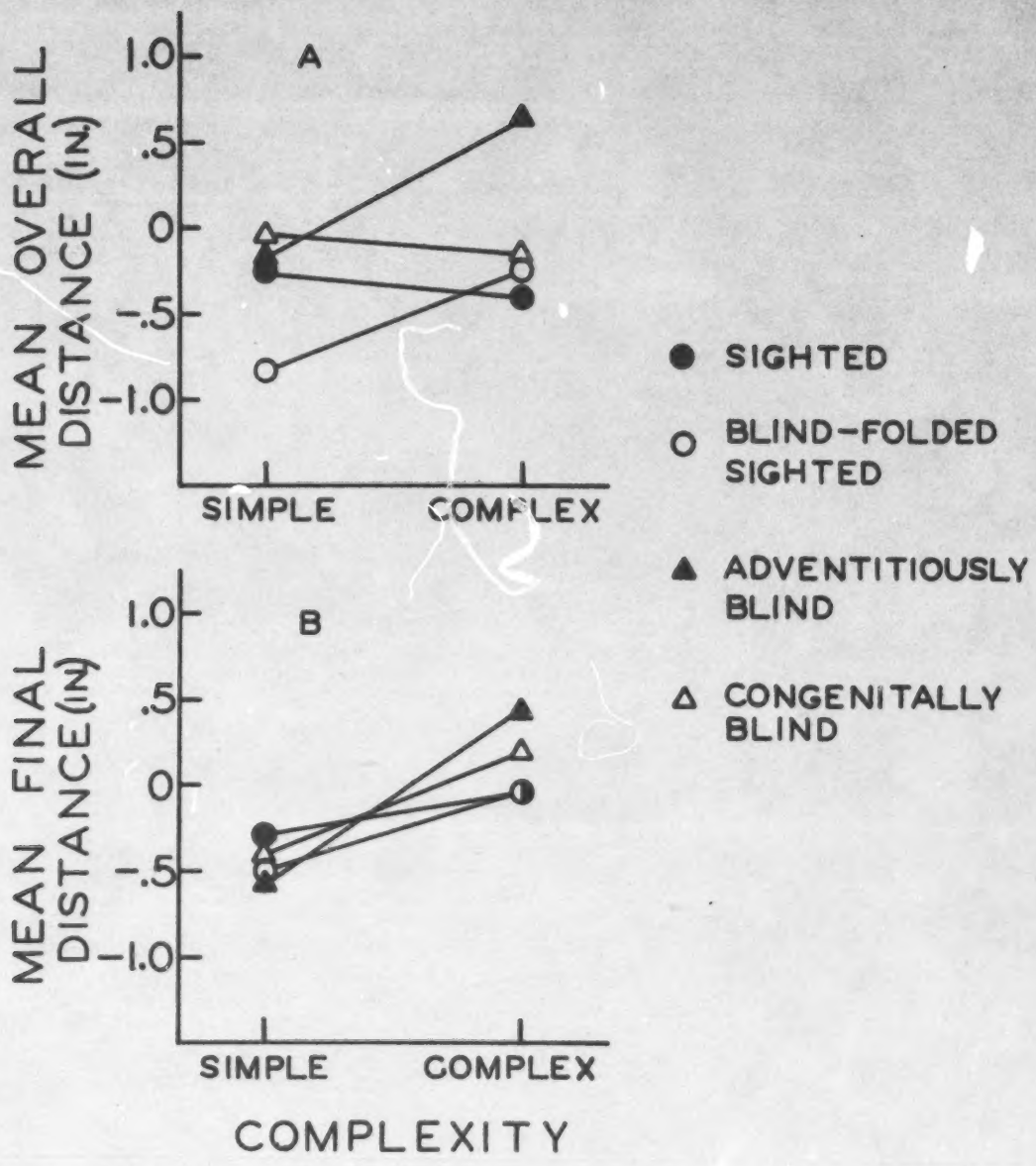
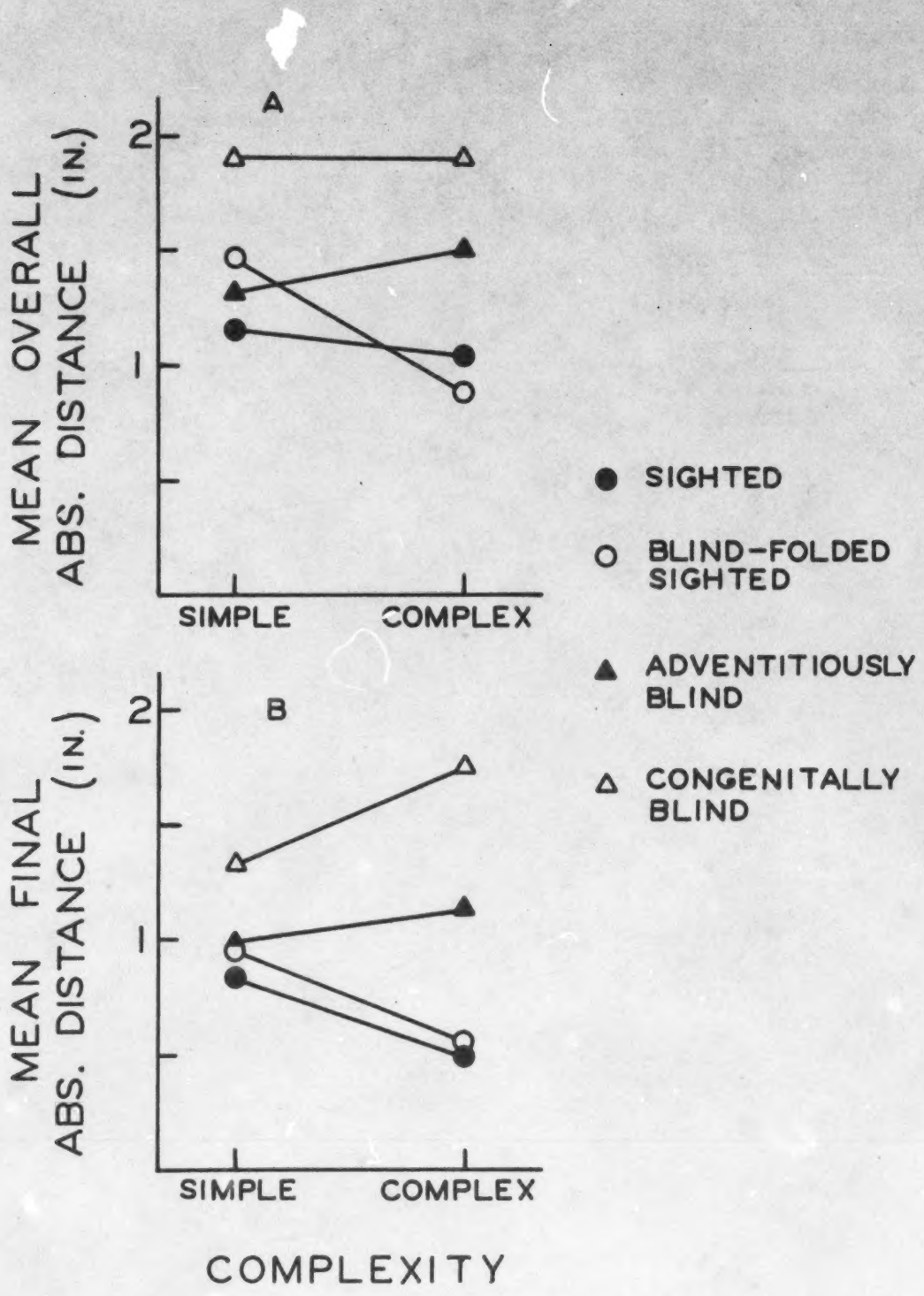

MEAN OVERALL DISTANCE (IN.)
1.0
.5
0
-.5
-1.0
A
SIMPLE
COMPLEX
MEAN FINAL DISTANCE (IN.)
1.0
.5
0
-.5
-1.0
B
SIMPLE
COMPLEX
COMPLEXITY
SIGHTED
BLIND-FOLDED SIGHTED
ADVENTITIOUSLY BLIND
CONGENITALLY BLIND

Figure 8. Mean overall absolute distance (A) and final absolute distance (B) as a function of task complexity in the tactual path learning task. A significant group main effect on overall absolute distance was found, but no other effects were significant.


A
MEAN OVERALL ABS. DISTANCE (IN.)
2
1
SIMPLE
COMPLEX
B
MEAN FINAL ABS. DISTANCE (IN.)
2
1
SIMPLE
COMPLEX
COMPLEXITY
SIGHTED
BLIND-FOLDED SIGHTED
ADVENTITIOUSLY BLIND
CONGENITALLY BLIND

dependent measures from the tactual path learning task indicated that the congenitally blind group performed worse in general than the other 3 groups. The adventitiously blind and blindfolded sighted groups were not significantly different from one another on any of the dependent measures except trials to criterion from the complex path. The sighted group was significantly better than the blindfolded sighted group on the trials to criterion measure from both the simple and complex paths. Also, the sighted group performed significantly better than the adventitiously blind group on the simple path as measured by trials to criterion and on the complex path as measured by trials to criterion and overall area. Although significance was not obtained for all measures, the sighted group consistently performed best and the congenitally blind group consistently performed worst on all measures, with the adventitiously blind and blindfolded sighted groups performing at intermediate levels. Also, the complex path was more difficult to learn than the simple path as indicated by significant effects of complexity on trials to criterion, overall and final similarity, and overall area.

Locomotor Path Task

Five dependent measures, mean similarity and 4 mean error scores (area, distance, absolute distance, and starting point) were analyzed in separate, univariate ANOVA procedures. Group and order were treated as between-subjects effects and complexity and novelty were treated as within-subjects effects in this 4x4x2x2 split-plot factorial design (SPF44.22; Kirk, 1968).

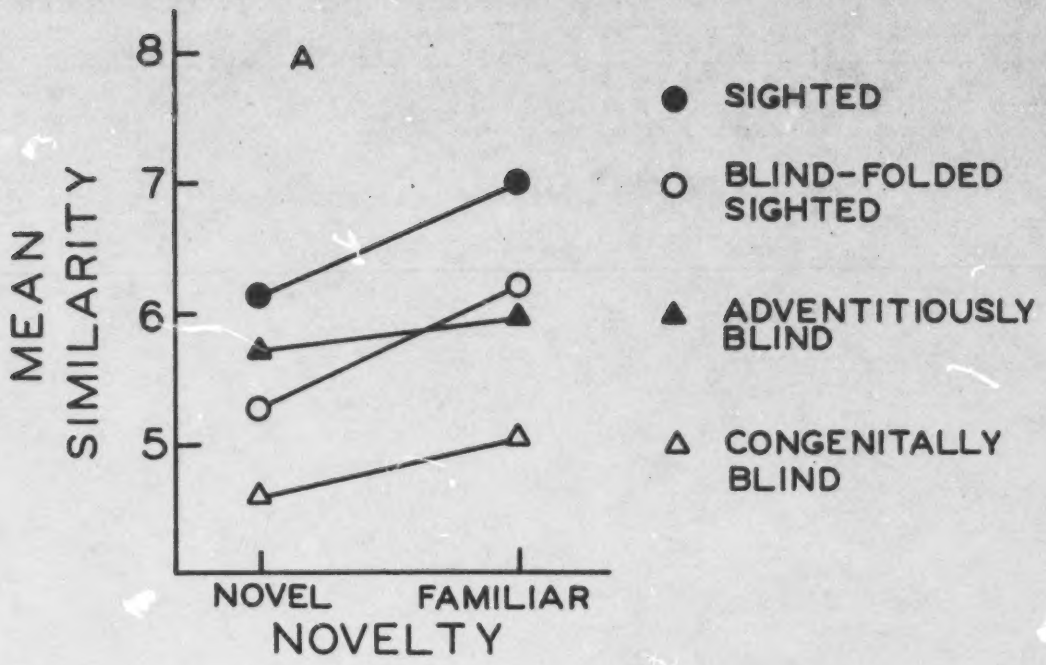
Similarity. The results of the analysis of variance on this measure indicated significant effects of groups, $F(3,68)=7.97$, $p < .001$, novelty, $F(1,68)=48.20$, $p < .001$, and complexity, $F(1,68)=150.12$, $p < .001$. In addition to these main effects, significant effects of the interactions of novelty with groups, $F(3,68)=3.06$, $p < .05$), and with complexity, $F(1,68)=20.62$, $p < .001$, were found.

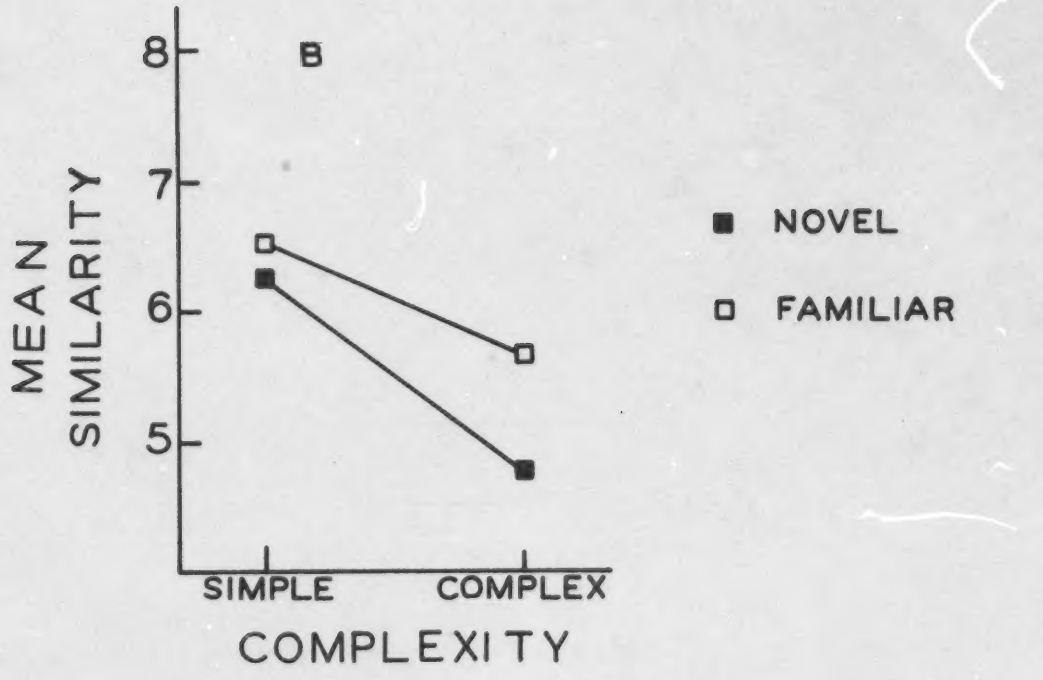
As illustrated in Fig. 9a and indicated by the simple effects of novelty within each group, the sighted group, $F(1,68)=11.08$, $p < .01$, and the blindfolded sighted group, $F(1,68)=7.84$, $p < .01$, performed significantly better on the familiar paths than on the novel paths whereas the congenitally blind, $F(1,68)=3.16$, $p > .05$, and apparently the adventitiously blind did not obtain significantly higher similarity ratings on the familiar paths than on the novel paths. Further, Neuman-Keuls analyses of group differences indicated that the congenitally blind obtained significantly lower similarity ratings than the sighted on the novel paths ($p < .05$) and on the familiar paths ($p < .05$) and that all other group differences were not significant.

Figure 9b illustrates the interaction between complexity and novelty. The novelty manipulation significantly affected performance on the complex paths, $F(1,68)=13.88$, $p < .01$, but not on the simple paths. Also, the complexity effect was significant on the familiar paths, $F(1,68)=12.08$, $p < .01$), where the difference was smallest, and therefore also on the novel paths, where the difference between mean similarity on the simple and complex paths was greater.

Overall, then, the congenitally blind performed worse than the sighted, with the blindfold sighted and adventitiously blind performing

Figure 9. (A) Mean similarity for each group as a function of path novelty in the locomotor path task. Significant effects of group, novelty, and the interaction of group and novelty were found. (B) Mean similarity for novel and familiar paths as a function of task complexity in the locomotor path task. Significant effects of complexity and the interaction of complexity and novelty were found.


A
8
7
6
5
MEAN SIMILARITY
NOVEL
FAMILIAR
NOVELTY
SIGHTED
BLIND-FOLDED SIGHTED
ADVENTITIOUSLY BLIND
CONGENITALLY BLIND

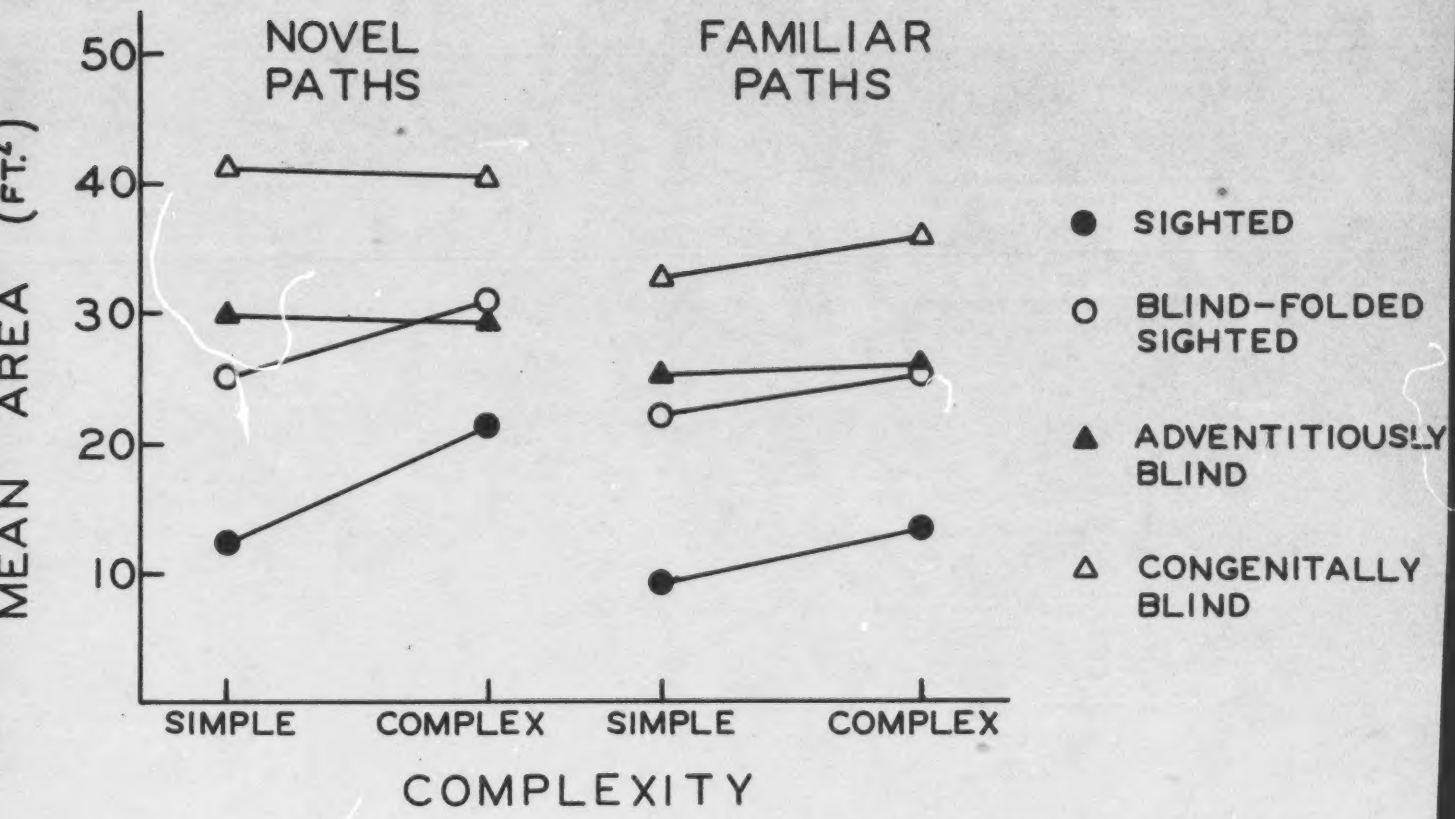

B
8
7
6
5
MEAN SIMILARITY
SIMPLE
COMPLEX
COMPLEXITY
NOVEL
FAMILIAR

somewhere in between. Also, the sighted and blindfolded sighted performed better on the familiar paths with which they had prior tactual experience, but the 2 blind groups did not. Finally, all groups performed better on the simple paths than on the complex paths, and this difference was greatest when the paths were novel.

Area. Mean area error scores are plotted for each group as a function of complexity under each novelty condition in Figure 10. The results of the analysis of variance indicated significant main effects of group, $F(3,68)=22.36$, $p < .001$, novelty, $F(1,68)=27.75$, $p < .001$, and complexity $F(1,68)=11.78$, $p < .001$, but no interaction effects. Error was greater on complex paths and on novel paths. A Neuman-Keuls analysis of group differences indicated that the sighted made significantly less error than any of the other three groups, which were not significantly different from one another. However, the congenitally blind made more errors than the adventitiously blind and the blindfolded sighted, who were very close in their errors (see Fig. 10).

Distance. The effect of the interaction of group and order was found to be significant, $F(9,68)=2.11$, $p < .05$, as well as the main effects of group $F(3,68)=2.82$, $p < .05$, and order, $F(3,68)=3.83$, $p < .02$. Analysis of the simple main effects indicated significant group differences under all order conditions: Order 1, $F(1,68)=7.04$, $p < .01$; Order 2, $F(1,68)=4.20$, $p < .05$; Order 3, $F(1,68)=11.37$, $p < .01$; Order 4, $F(1,68)=5.85$, $p < .05$. A Neuman-Keuls analysis of group differences identified a significant difference between the sighted and both of the blind groups in Order 3 ($p < .05$ in both cases), but no other

Figure 10. Mean area for each group as a function of path novelty and task complexity in the locomotor path task. Significant group, novelty and complexity effects were found.

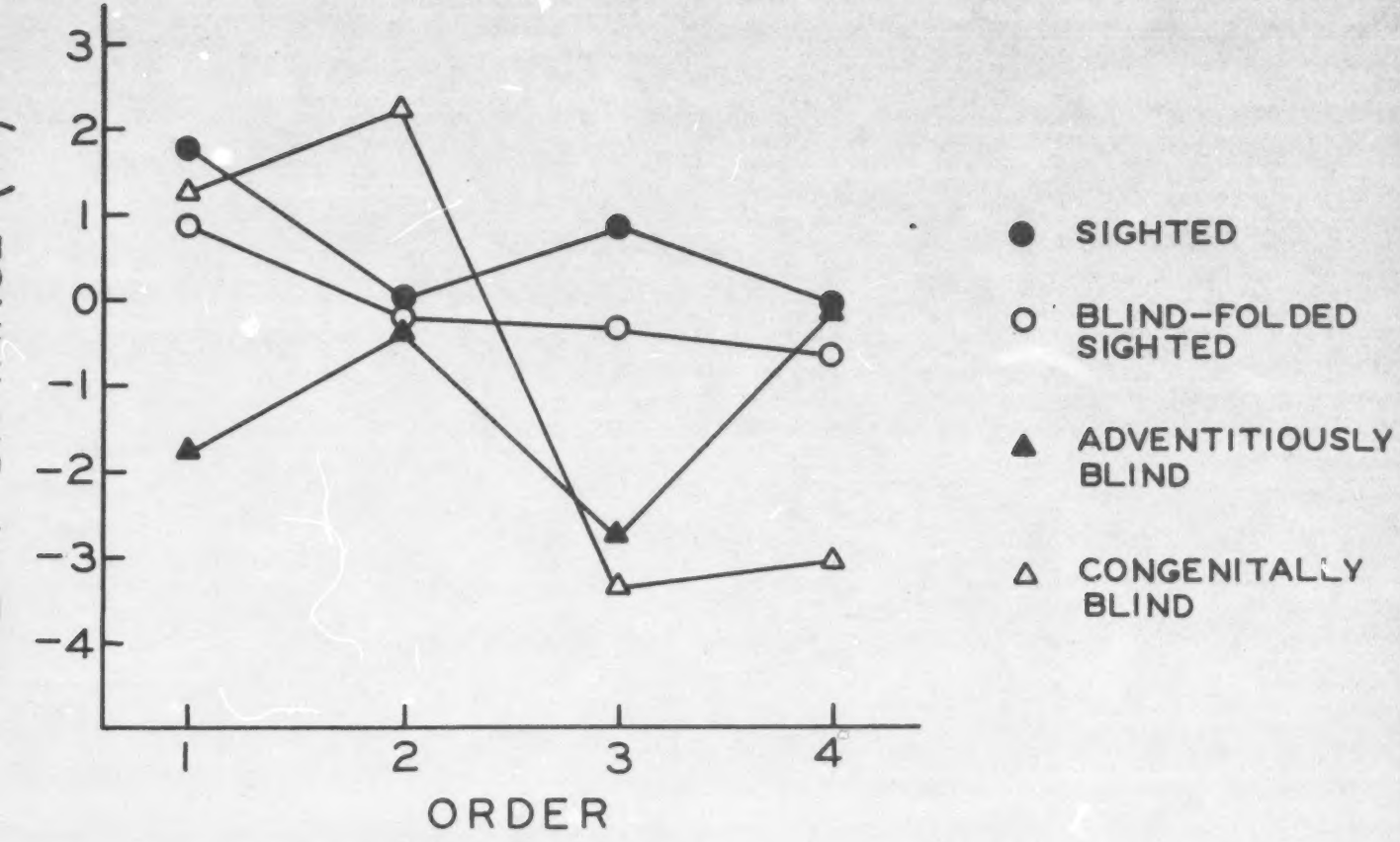

NOVEL PATHS
FAMILIAR PATHS
50
40
30
20
10
MEAN AREA (FT.²)
SIMPLE
COMPLEX
SIMPLE
COMPLEX
COMPLEXITY
SIGHTED
BLIND-FOLDED SIGHTED
ADVENTITIOUSLY BLIND
CONGENITALLY BLIND

significant differences. However, inspection of Figure 11 suggests that the adventitiously blind gave shorter estimations of the length of the paths in Order 1 than the other 3 groups, the congenitally blind gave longer estimations of the length of the paths than the other 3 groups in Order 2 and shorter estimations of the length of the paths than the other 3 groups in Order 4. The simple main effects of order within each group indicated significant effects of order in the congenitally blind $F(1,68)=23.81$, $p < .001$, and in the adventitiously blind, $F(1,68)=4.46$, $p < .05$, but no effect of order in the sighted, $F(1,68)=2.01$, $p > .10$. Order differences in the blindfolded sighted were less than in the sighted group and therefore assumed also to be non-significant. Neuman-Keul's analysis of order differences within each group indicated that the congenitally blind gave longer estimations of paths when the simple paths occurred first (orders 1 and 2) than when the complex paths occurred first ($p < .01$). Order differences in the adventitiously blind were not significant by the Neuman-Keuls analysis, but figure 11 suggests that these subjects underestimated the length of paths when familiar paths occurred first (orders 1 and 3) relative to task orders in which novel paths occurred first.

In addition to the group x order effect there was a significant complexity effect, $F(1,68)=29.21$, $p < .001$, and no significant interactions of complexity with any other manipulation. The length of complex paths were slightly overestimated (mean = +.36 ft.) whereas the length of the simple paths was underestimated (mean = -1.0 ft.).

Absolute Distance. The group main effect was significant,

Figure 11. Mean distance for each group is plotted as a function of task order in the locomotor path task. Significant effects of group, order, complexity, and the interaction of group and order were found.


3
2
1
0
-1
-2
-3
-4
1
2
3
4
ORDER
SIGHTED
BLIND-FOLDED SIGHTED
ADVENTITIOUSLY BLIND
CONGENITALLY BLIND

$F(3,68)=7.45$, $p < .001$, but was modified by a significant group by complexity interaction effect, $F(3,68)=6.45$, $p < .001$, which indicated that the congenitally blind made larger errors on the simple paths than on the complex paths, $F(1,68)=8.00$, $p < .01$, but that the other 3 groups made distance errors of similar magnitude on the simple and complex paths (see Fig. 12). Further, a Neuman-Keuls analysis of group differences indicated that the congenitally blind made larger errors than any of the other 3 groups on the simple paths ($p < .01$ when compared with sighted and blindfolded sighted, $p < .05$ when compared with adventitiously blind). Group differences on the complex paths were non-significant.

Starting Point. The only significant effect on this measure was the main effect of group, $F(3,68)=16.92$, $p < .001$. A Neuman-Keuls analysis of group differences indicated that the sighted made smaller errors than the congenitally blind ($p < .01$) and the blindfolded sighted ($p < .05$). All other group differences were non-significant (see Fig. 13).

Transfer scores. Significant effects involving the novelty factor included the interactions of novelty with group and novelty with complexity on mean similarity, and the main effect of novelty on mean area. Thus, there were no differences between groups or complexity conditions on the area, absolute distance and starting point transfer scores. However, the interaction effects involving novelty on similarity indicated that transfer was greater for the sighted and blindfolded sighted groups than for the two blind groups and greater for complex paths than for simple paths.

Figure 12. Mean absolute distance for each group as a function of task complexity in the locomotor path task. Significant effects of group and the interaction of group and complexity were found.

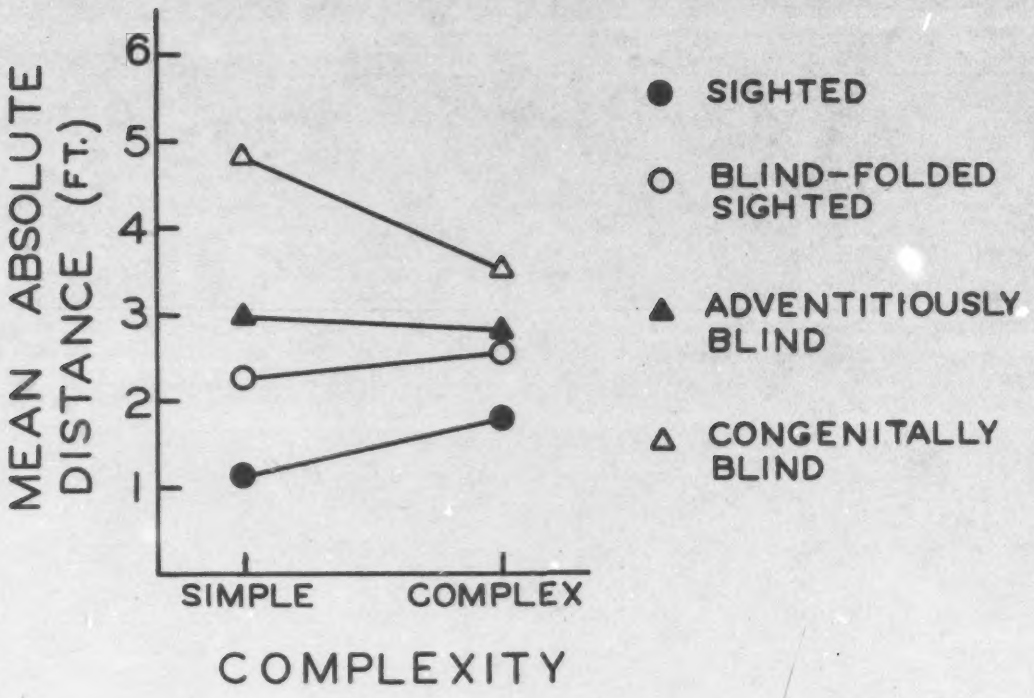
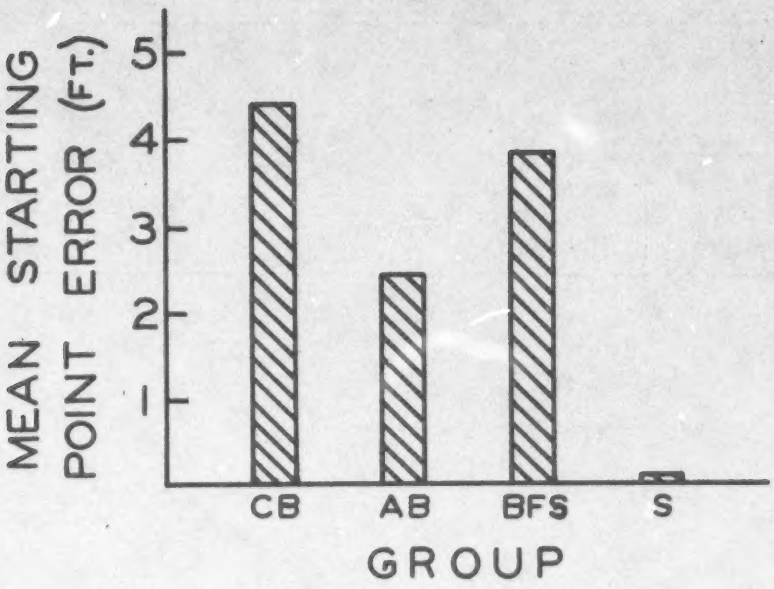

MEAN ABSOLUTE DISTANCE (FT.)
6
5
4
3
2
1
SIMPLE
COMPLEX
COMPLEXITY
SIGHTED
BLIND-FOLDED SIGHTED
ADVENTITIOUSLY BLIND
CONGENITALLY BLIND

Figure 13. Mean starting point error for each group in the locomotor path task. Mean errors were averaged across all path conditions (S = sighted; BFS = blind-folded sighted; AB = adventitiously blind; CB = congenitally blind).


MEAN STARTING POINT ERROR (FT.)
1
2
3
4
5
CB
AB
BFS
S
GROUP

In summary, the analyses of variance on the dependent measures from the locomotor path task indicated that in general the sighted group performed best and the congenitally blind group performed worst. The performances of the blindfolded sighted and adventitiously blind groups were intermediate and not significantly different from one another. The familiar paths were more easily learned than the novel paths, especially for the sighted and blindfolded sighted groups. Simple paths were also more easily learned. There were no consistent effects of task order except on distance, where the results were very complex and largely unincerpretable.

RESULTS: MULTIPLE REGRESSION ANALYSIS

This analysis was performed to determine the relative importance of visual experience and the other kinds of perceptual-motor experience which were measured by the experience questionnaire. A difficulty arose when the number of subjects in the adventitiously blind group was much too small to allow a meaningful analysis of all the experience variables measured at each of the four age periods. As noted in the questionnaire development section, some of the subscales were unreliable for certain age periods and were therefore not used in the present study. However, 15 early experience subscales were judged indispensible to an analysis of the importance of organism-environment interactions in accounting for the spatial skills of blind people. These subscales included 5 measures of social stimulation (adult stimulation during each of the 4 age periods and total number of siblings), measures of manipulative activity for the age periods 5-10 years and 10-16 years, a measure of gross physical activity at each of the 4 age periods and a measure of environmental variety at each of the 4 age periods.

In an effort to reduce the number of experience measures to be used as predictor variables in the multiple regression analysis, the intercorrelations of the measures were examined. To reduce the number of predictor variables, scale scores which were correlated more than .70 across adjacent age periods were summed to yield a single score for that particular experience measure over a larger age range. For example, the environmental variety scale scores for the age periods 5-10 years and 10-16 years were correlated .78 and were therefore

summed and treated as a single measure of experience. In the case of the adult stimulation scales, the intercorrelations of the scores from all 4 age periods ranged from .70 to .91. A single adult stimulation score computed as the sum of the adult stimulation scores from all 4 age periods was used in the regression analysis. In the same way, the physical activity scales from the age periods 5-10 years and 10-16 years (r=.83) were combined, as were the manipulative activity scales from the same two age periods (r=.79).

This procedure reduced the number of early experience variables to 9. When combined with the variable duration of early vision and verbal IQ as a control variable, there were still too many predictor variables to be used in a multiple regression analysis of only the adventitiously blind subjects. It was reasoned that the congenitally blind subjects could be included in the analysis since predictions about their performance on the spatial tasks were identical to those for the adventitiously blind, i.e., that either the duration of vision (0 for congenitally blind subjects) and/or other experience measures might account for their spatial performance. Thus, 47 subjects were considered for the analysis. However, a few of the subjects did not complete all spatial tasks and there were several parent questionnaires which were either not returned or returned with incomplete information. Missing scores were distributed evenly across variables, and therefore pairwise deletion was used in the analysis. Using this technique, correlations between variables are calculated using all available data, but the degrees of freedom for the regression analysis is based upon the minimum number of cases used in calculating any correlation coefficient

required for the analysis. The total degrees of freedom was 35 for the analysis of the tactual pattern discrimination tasks and 34 for the analysis of the tactual path learning tasks and the locomotor path tasks.

The analysis was carried out in a similar manner for each dependent variable measured in the spatial tasks. Verbal IQ was forced into the equation first in order to account and control for variance in the dependent measure which might be linked to the intelligence of subjects. After partialling the correlation of verbal IQ with the dependent variable, a stepwise forward solution of the regression equation was made with the use of an IBM360 computer and an SPSS multiple regression computer program (Nie, Hull, Jenkins, Steinbrenner & Berit, 1975). During the solution, all the experience variables (including early vision) were considered as predictors for inclusion in the regression equation. On any step, the non-included predictor variable which accounted for the greatest increase (ΔR^2) in the total proportion of variance accounted for (R^2) in the dependent variable was entered into the equation if that ΔR^2 was significant. As long as a single predictor variable significantly increased R^2 the solution was continued. However, if the addition of any single predictor variable to the regression equation would not significantly increase R^2 but the addition of 2 predictor variables would significantly increase R^2, then those 2 variables were entered on one step into the equation. If the addition of any 1 or 2 predictor variables to the equation would not significantly increase R^2 but the addition of 3 would produce a significant ΔR^2, then those 3 variables were entered on one step into

the equation. This procedure continued until a significant ΔR^2 could not be accounted for by any combination of predictor variables not already entered into the equation. All dependent variables were regressed on the predictor variables separately for each unique task, i.e., simple, complex, novel-simple, etc. The reader may be interested in the intercorrelations of the dependent variables, which in general were very high (see Appendix C).

The resulting ΔR^2's and standardized regression coefficients (b) are shown in Tables 2 to 10 with the step on which variables were entered. Standardized regression coefficients are denoted by a "b" instead of the usual β in order to avoid confusion with the dependent variable "response threshold" (β) from the tactual pattern discrimination task. It should also be noted that the first entry in each table is verbal IQ which was entered into the prediction equations on step 1 as a control variable. Therefore the numbers entered in the ΔR^2 columns for verbal IQ are actually the squared simple correlations between it and the dependent variables.

Tactual Pattern Discrimination Task

Results of the regression analysis for both d' and β are presented in Table 2 for the simple and complex tasks. Early vision was the only significant predictor of d' in the simple task (ΔR^2=.11, $F(1,32)=4.20$, $p < .05$). In the complex task, verbal IQ accounted for a significant proportion of d' variance (r^2=.15, $F(1,33)=5.96$, $p < .05$) and the combination of early vision, manipulative activity from 5-16 years and physical activity from 5-16 years entered into the equation on step 2

Table 2. Significant Contributions to the Amount of Variance Accounted for (ΔR^2) and Standardized Regression Coefficients (b) of Predictor Variables for Each Dependent Variable in the Tactual Pattern Discrimination Task

Predictor Variable	Dependent Variable: d' Simple		d' Complex		β Simple		β Complex	
	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b
Verbal IQ	.03(1)*	.16	.15(1)	.33	.02(1)*	-.41	.02(1)*	.13
Early Vision	.11(2)	.34	.07(2)	.28	--	--	.16(2)	.53
Physical Activity (0-2yrs)	--	--	--	--	--	--	--	--
Physical Activity (2-5yrs)	--	--	--	--	--	--	--	--
Physical Activity (5-16yrs)	--	--	.07(2)	-.36	--	--	.10(3)	-.34
Environmental Variety(0-2yrs)	--	--	--	--	.08(2)	.45	--	--
Environmental Variety(2-5yrs)	--	--	--	--	--	--	--	--
Environmental Variety(5-16yrs)	--	--	--	--	.07(2)	-.17	--	--
Manipulative Activity(5-16yrs)	--	--	.09(2)	.33	.11(2)	.46	--	--
Adult Stimulation	--	--	--	--	.06(2)	-.50	--	--
Number of Siblings	--	--	--	--	.09(3)	-.32	--	--
R^2	.14		.38		.43		.28	
Adjusted R^2	0		.19		.25		.05	

1. Number in parentheses indicates step of the regression solution on which the predictor variable was entered.

* Non-significant r^2 of verbal IQ on step 1.

of the solution and accounted for a significant ΔR^2 of .23 (F3,30)= 4.09, $p < .05$. When β was regressed on verbal IQ there was no significant r^2 in either the simple or complex tasks. In the simple task, the predictor variables environmental variety from 0-2 years and from 5-16 years, manipulative activity from 5-16 years and adult stimulation were entered together on step 2 and accounted for a total ΔR^2 of .32, F(4,29)=3.51, $p < .05$. The other measure of social stimulation, number of siblings, accounted for a significant ΔR^2 of .09 on step 3, F(1,28)=4.61, $p < .05$.

Tactual Path Learning Task

Mean learning performance measures were computed separately for all learning trials and for the final 2 learning trials of each task. Results of the multiple regression analyses for the overall measures are shown in Tables 3 & 4 and will be presented first.

Significant predictors of trials to criterion in the simple task included verbal IQ ($r^2 = .13$) on step 1, F(1,32)=4.91, $p < .05$, early vision ($\Delta R^2 = .18$) on step 2, F(1,31)=8.30, $p < .01$, and environmental variety from 5-16 years ($\Delta R^2 = .11$) on step 3, F(1,31)=4.18, $p < .05$.

Significant predictors of mean overall similarity in the simple task included verbal IQ ($r^2 = .15$) on step 1, F(1,32)=5.75, $p < .05$, early vision ($\Delta R^2 = .15$) on step 2, F(1,31)=6.60, $p < .05$, physical activity from 2-5 years ($\Delta R^2 = .21$) on step 3, F(1,30)=13.14, $p < .01$, physical activity from 5-16 years ($\Delta R^2 = .09$) on step 4, F(1,29)=6.92, $p < .05$, and physical activity from 0-2 years ($\Delta R^2 = .07$) on step 5, F(1,28)=6.36, $p < .05$. In the complex task, significant predictors of

mean overall similarity included verbal IQ (r^2=.19), on step 1, F(1,32)-7.66, p <.01, early vision (ΔR^2=.13) on step 2, F(1,31)=6.05, p <.05, and the combination of physical activity from all age periods (ΔR^2=.16) on step 3, F(3,28)=2.98, p <.05.

Significant predictors of mean overall area in the simple task included verbal IQ (r^2=.15) on step 1, F(1,32)=5.79, p <.05, and the combination of early vision and physical activity from 2-5 years on step 2 (ΔR^2=.09), F(2,30)=4.72, p <.05. In the complex task, significant ΔR^2s were predicted by verbal IQ (r^2=.17) on step 1, F(1,32)=6.70, p <.05, and early vision (ΔR^2=.14) on step 2, F(1,31)=6.22, p <.05.

Mean overall distance error was significantly predicted only by physical activity from 2-5 years in both the simple task (ΔR^2=.16), F(1,31)=6.05, p <.05, and the complex task (ΔR^2=.12), F(1,31)=4.17, p <.05. No other predictor or combination of predictors accounted for significant ΔR^2s. On the other hand, the mean overall absolute distance error was significantly predicted by several variables. In the simple task, these included verbal IQ (r^2=.13) on step 1, F(1,32)=4.98, p <.05, physical activity from 5-16 years (ΔR^2=.15) on step 3, F(1,30)= 7.82, p <.01, number of siblings (ΔR^2=.08) on step 4, F(1,29)=4.54, p <.05, and the combination of early vision, physical activity from 0-2 years and environmental variety from 5-16 years on step 5 (ΔR^2=.14), F(3,26)=3.24, p <.05.

Results of the multiple regression analyses of the performance measures averaged from the final 2 learning trials appear in Tables 5 and 6. Significant predictors of final similarity in the simple task included verbal IQ (r^2=.12) on step 1, F(1,32)=4.56, p <.05, early

Table 3. Significant Contributions to the Amount of Variance Accounted for (ΔR^2) and Standardized Regression Coefficients (b) of Predictor Variables for the Overall Performance Measures on the Simple Tactual Path

Predictor Variable	Dependent Variable: Trials to Criterion		Similarity		Area		Distance		Absolute Distance	
	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b
Verbal IQ	.13(1)	-.23	.15(1)	.44	.15(1)	-.45	.00(1)*	.04	.13(1)	-.53
Early Vision	.18(2)	-.50	.15(2)	.40	.09(2)	-.39	--	--	.05(5)	-.32
Physical Activity (0-2yrs)	--	--	.07(5)	.31	--	--	--	--	.05(5)	-.27
Physical Activity (2-5yrs)	--	--	.21(3)	-.85	.11(2)	.36	.16(2)	1.78	.14(2)	.87
Physical Activity (5-16yrs)	--	--	.09(4)	.40	--	--	--	--	.15(3)	-.25
Environmental Variety (0-2yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (2-5yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (5-16yrs)	.13(3)	-.38	--	--	--	--	--	--	.04(5)	-.28
Manipulative Activity (5-16yrs)	--	--	--	--	--	--	--	--	--	--
Adult Stimulation	--	--	--	--	--	--	--	--	--	--
Number of Siblings	--	--	--	--	--	--	--	--	.08(4)	-.23
R^2	.44		.67		.35		.16		.64	
Adjusted R^2	.26		.57		.15		0		.54	

1. Number in parentheses indicates step of the regression solution on which the predictor variable was entered.

* Non-significant r^2 of verbal IQ on step 1

Table 4. Significant Contributions to the Amount of Variance Accounted for (ΔR^2) and Standardized Regression Coefficients (b) of Predictor Variables for the Overall Performance Measures on the Complex Tactual Path

Predictor Variable	Dependent Variable: Trials to Criterion		Similarity		Area		Distance		Absolute Distance	
	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b
Verbal IQ	.10(1)*	-.29	.19(1)	.43	.17(1)	-.39	.03(1)*	.04	.05(1)*	-.26
Early Vision	.11(2)	-.33	.13(2)	.34	.14(2)	-.37	--	--	.05(2)	-.31
Physical Activity (0-2yrs)	--	--	.07(3)	.31	--	--	--	--	.07(2)	-.31
Physical Activity (2-5yrs)	--	--	.05(3)	-.52	--	--	.12(2)	1.80	.06(2)	.42
Physical Activity(5-16yrs)	--	--	.04(3)	.27	--	--	--	--	--	--
Environmental Variety(0-2yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety(2-5yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety(5-16yrs)	--	--	--	--	--	--	--	--	.10(2)	.16
Manipulative Activity(5-16yrs)	--	--	--	--	--	--	--	--	--	--
Adult Stimulation	--	--	--	--	--	--	--	--	--	--
Number of Siblings	--	--	--	--	--	--	--	--	--	--
R^2	.21		.48		.31		.15		.33	
Adjusted R^2	0		.32		.15		0		.12	

1. Number in parentheses indicates step of the regression solution on which the predictor variable was entered.

* Non-significant r^2 of verbal IQ on step 1

vision (ΔR^2=.12) on step 2, F(1,31)=4.88, p <.05, physical activity from 2-5 years (ΔR^2=.20) on step 3, F(1,30)=10.72, p <.01, physical activity from 0-2 years (ΔR^2=.08) on step 4, F(1,29)=4.66, p <.05, and physical activity from 5-16 years (ΔR^2=.07) on step 5, F(1,28)= 5.14, p <.05. In the complex task, final similarity was significantly predicted by verbal IQ (r^2=.22) on step 1, F(1,32)=9.14, p <.05, and the combination of early vision, physical activity from 2-5 years, and number of siblings on step 2 (ΔR^2=.19), F(3,29)=3.02, p <.05.

Final area error on the simple task was significantly predicted by verbal IQ (r^2=.12) on step 1, F(1,32)=4.34, p <.05, physical activity from 2-5 years (ΔR^2=.12) on step 2, F(1,31)=4.73, p <.05, early vision (ΔR^2=.14) on step 3, F(1,30)=6.70, p <.05, and number of siblings (ΔR^2=.08) on step 4, F(1,29)=4.47, p <.05. Final area error on the complex task was significantly predicted only by verbal IQ (r^2=.25) on step 1, F(1,32)=10.66, p <.01.

Significant predictors of final distance error on the simple task included physical activity from 2-5 years (ΔR^2=.25) on step 2, F(1,31)= 10.40, p <.01, and physical activity from 5-16 years (ΔR^2=.11) on step 3, F(1,30)=5.28, p <.05. There were no significant predictors of final distance error on the complex task. There were also no significant predictors of final absolute distance error on the complex task. On the simple task, however, final absolute distance error was significantly predicted by verbal IQ (r^2=.13) on step 1, F(1,32)=4.75, p <.05, physical activity from 2-5 years (ΔR^2=.14) on step 2, F(1,31)=6.19, p <.05, physical activity from 0-2 years (ΔR^2=.12) on step 3, F(1,30)=5.84, p <.05, and the combination of number of siblings, early vision, and

Table 5. Significant Contributions to the Amount of Variance Accounted for (ΔR^2) and Standardized Regression Coefficients (b) of Predictor Variables for the Final Performance Measures on the Simple Tactual Path.

Predictor Variable	Dependent Variable: Similarity		Area		Absolute Distance		Starting Point	
	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b
Verbal IQ	.12(1)	.40	.12(1)	-.52	.00(1)*	.03	.13(1)	-.50
Early Vision	.12(2)	.36	.14(3)	-.32	--	--	.03(4)	-.27
Physical Activity (0-2yrs)	.08(4)	.33	--	--	--	--	.12(3)	-.44
Physical Activity (2-5yrs)	.20(3)	-.82	.12(2)	.57	.25(2)	.78	.14(2)	.73
Physical Activity (5-16yrs)	.07(5)	.36	--	--	.11(3)	-.42	--	--
Environmental Variety(0-2yrs)	--	--	--	--	--	--	--	--
Environmental Variety(2-5yrs)	--	--	--	--	--	--	--	--
Environmental Variety(5-16yrs)	--	--	--	--	--	--	--	--
Manipulative Activity(5-16yrs)	--	--	--	--	--	--	.06(4)	.27
Adult Stimulation	--	--	--	--	--	--	--	--
Number of Siblings	--	--	.08(4)	-.33	--	--	.07(4)	-.24
R^2	.59		.46		.36		.55	
Adjusted R^2	.46		.29		.16		.41	

1. Number in parentheses indicates step of the regression solution on which the predictor variable was entered.

* Non-significant r^2 of verbal IQ on step 1.

Table 6. Significant Contributions to the Amount of Variance Accounted for (ΔR^2) and Standardized Regression Coefficients (b) of Predictor Variables for the Final Performance Measures on the Complex Tactual Path

Predictor Variable	Dependent Variable: Similarity		Area		Absolute Distance		Starting Point	
	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b
Verbal IQ	.22(1)	.59	.25(1)	-.50	--	--	--	--
Early Vision	.07(2)	.27	--	--	--	--	--	--
Physical Activity (0-2yrs)	--	--	--	--	--	--	--	--
Physical Activity (2-5yrs)	.06(2)	-.35	--	--	--	--	--	--
Physical Activity (5-16yrs)	--	--	--	--	--	--	--	--
Environmental Variety(0-2yrs)	--	--	--	--	--	--	--	--
Environmental Variety(2-5yrs)	--	--	--	--	--	--	--	--
Environmental Variety(5-16yrs)	--	--	--	--	--	--	--	--
Manipulative Activity(5-16yrs)	--	--	--	--	--	--	--	--
Adult Stimulation	--	--	--	--	--	--	--	--
Number of Siblings	.06(2)	.28	--	--	--	--	--	--
R^2	.41		.25		--		--	
Adjusted R^2	.22		.01		--		--	

1. Number in parentheses indicates step of the regression solution on which the predictor variable was entered.

manipulative activity from 5-16 years on step 4 (ΔR^2=.16), F(3,27)= 3.20, p <.05.

The multiple regression analysis of the relationship between early experience and tactual path learning indicated that early vision was a very consistent predictor of performance on both simple and complex paths. However, final performance measures from the complex path were generally not predicted well by any of the early experience variables. Other consistent predictors of tactual path learning included the physical activity subscales and number of siblings. Manipulative activity from 5-16 years and environmental variety from 5-16 years were occasional predictors of performance, whereas environmental variety from 0-2 years and 2-5 years, and adult stimulation were not predictive of any performance measure. Verbal IQ consistently accounted for significant proportions of performance variance when treated as a control variable on step 1 of the regression solutions. Together, the predictor variables were able to account for ΔR^2s of .16-.52 (mean = .37) above the prediction by verbal IQ on the simple path and ΔR^2s of 0-.29 (mean = .13) on the complex path. There was a slight tendency for prediction of overall performance (mean ΔR^2 = .26) to be greater than prediction of final performance (mean ΔR^2 = .18).

Locomotor Path Task

Performance scores. The results of the multiple regression analyses of the dependent measures of performance in the locomotor path task are tabled separately for each path condition in Tables 7 to 10. The results will be presented separately for each path condition.

On the novel-simple path (see Table 7) verbal IQ accounted for significant ΔR^2s on step 1 of the regression solution for the dependent measures mean similarity (r^2=.25), F(1,32)=10.68, p <.01, mean area (r^2=.18), F(1,32)=7.16, p <.05, and mean absolute distance (r^2=.14), F(1,32)=5.06, p <.05. Number of siblings accounted for a significant ΔR^2 of .14 on step 2 of the solution for the dependent measure mean area, F(1,31)=6.34, p <.05. The combination of number of siblings and physical activity from 2-5 years accounted for a significant ΔR^2 of .17 on step 2 of the solution for mean starting point error, F(2,30)=3.35, p <.05.

Significant predictors of performance on the novel-complex path included verbal IQ, physical activity measures, and the number os siblings (see Table 8). Verbal IQ accounted for significant r^2s on step 1 of the regression solution for the dependent measures mean similarity (r^2=.25), F(1,32)=9.96, p <.01, mean area (r^2=.22), F(1,32)=9.06, p <.01, and mean absolute distance (r^2=.15, F(1,32)=5.82, p <.05. Number of siblings accounted for significant ΔR^2s on step 2 of the solution for mean similarity (ΔR^2=.13), F(1,31)=6.41, p <.05, and mean area (ΔR^2=.12), F(1,31)=5.58, p <.05. Physical activity from 2-5 years accounted for a significant ΔR^2 of .13 on step 2 of the regression solution for mean distance, F(1,31)=4.81, p <.05, and combined with physical activity from 5-16 years on step 2 of the solution for mean starting point error to account for a ΔR^2 of .24, F(2,30)=5.13, p <.05. The combination of physical activity from 0-2 years and from 2-5 years combined on step 3 of the solution for mean similarity, accounting for a ΔR^2 of .12, F(2,29)=3.47, p <.05.

Table 7. Significant Contributions to the Amount of Variance Accounted for (ΔR^2) and Standardized Regression Coefficients (b) of Predictor Variables for Each Dependent Variable on the Novel-Simple Locomotor Path

Predictor Variable	Dependent Variable: Similarity		Area		Distance		Absolute Distance		Starting Point	
	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b
Verbal IQ	.25(1)	.50	.18(1)	-.50	--	--	.14(1)	-.37	.05(1)*	-.39
Early Vision	--	--	--	--	--	--	--	--	--	--
Physical Activity (0-2yrs)	--	--	--	--	--	--	--	--	--	--
Physical Activity (2-5yrs)	--	--	--	--	--	--	--	--	.09(2)	.34
Physical Activity (5-16yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (0-2yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (2-5yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (5-16yrs)	--	--	--	--	--	--	--	--	--	--
Manipulative Activity (5-16yrs)	--	--	--	--	--	--	--	--	--	--
Adult Stimulation	--	--	--	--	--	--	--	--	--	--
Number of Siblings	--	--	.14(2)	-.38	--	--	--	--	.08(2)	-.42
R^2	.25		.32		--		.14		.22	
Adjusted R^2	.01		.11		--		0		0	

1. Number in parentheses indicates step of the regression solution on which the predictor variable was entered.

* Non-significant r^2 of verbal IQ on step 1

Table 8. Significant Contributions to the Amount of Variance Accounted for (ΔR^2) and Standardized Regression Coefficients (b) of Predictor Variables for Each Dependent Variable on the Novel-Complex Locomotor Path

Predictor Variable	Dependent Variable: Similarity		Area		Distance		Absolute Distance		Starting Point	
	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b
Verbal IQ	.25(1)	.57	.22(1)	-.54	.07(1)*	-.17	.15(1)	-.39	.06(1)*	-.35
Early Vision	--	--	--	--	--	--	--	--	--	--
Physical Activity (0-2yrs)	.05(3)	.31	--	--	--	--	--	--	--	--
Physical Activity (2-5yrs)	.07(3)	-.37	--	--	.13(2)	-.37	--	--	.10(2)	-.48
Physical Activity (5-16yrs)	--	--	--	--	--	--	--	--	.14(2)	.62
Environmental Variety (0-2yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (2-5yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (5-16yrs)	--	--	--	--	--	--	--	--	--	--
Manipulative Activity (5-16yrs)	--	--	--	--	--	--	--	--	--	--
Adult Stimulation	--	--	--	--	--	--	--	--	--	--
Number of Siblings	.13(2)	.41	.12(2)	-.35	--	--	--	--	--	--
R^2	.50		.34		.20		.15		.30	
Adjusted R^2	.34		.13		0		0		.08	

1. Number in parentheses indicates step of the regression solution on which the predictor variable was entered.

* Non-significant r^2 of verbal IQ on step 1

On the familiar-simple path (see Table 9), verbal IQ accounted for significant r^2s on step 1 of the solutions for mean similarity (r^2=.20), F(1,32)=8.20, p <.01, mean area (r^2=.17), F(1,32)=6.51, p <.05, and mean starting point error (r^2=.15), F(1,32)=5.42, p <.01. Early vision accounted for a significant ΔR^2 of .10 on step 2 of the solution for mean similarity F(1,31)=4.22, p <.05, and combined with physical activity from 2-5 years on step 2 of the solution for mean absolute distance (ΔR^2=.20), F(2,30)=4.67, p <.05. Physical activity from 0-2 years accounted for a significant ΔR^2 of .13 on step 3 of the solution for mean absolute distance, F(1,29)=7.45, p <.05, and combined with physical activity from 2-5 years and environmental variety from 5-16 years on step 2 of the solution for mean distance (ΔR^2=.26), F(3,29)=3.51, p <.05. Physical activity from 2-5 years also combined with number of siblings on step 3 of the regression solution for mean similarity (ΔR^2=.14), F(2,29)=3.53, p <.05. In addition, number of siblings alone accounted for a ΔR^2 of .11 on step 2 of the solution for mean area, F(1,31)=4.76, p <.05.

On the familiar-complex path (see Table 10), verbal IQ accounted for significant r^2s on step 1 of the solutions for the regression equations predicting mean similarity (r^2=.22), F(1,32)=9.17, p <.01, mean absolute distance (r^2=.20), F(1,32)=8.07, p <.01. The 3 physical activity predictors accounted for a significant ΔR^2 of .27 on step 2 of the solution for mean distance, F(3,29)=3.46, p <.05. Physical activity from 0-2 years entered on step 2 of the solution for mean absolute distance and accounted for a ΔR^2 of .11, F(1,31)=4.94, p <.05, and physical activity from 2-5 years entered on step 3 of the same solution,

Table 9. Significant Contributions to the Amount of Variance Accounted for (ΔR^2) and Standardized Regression Coefficients (b) of Predictor Variables for Each Dependent Variable on the Familiar-Simple Locomotor Path

Predictor Variable	Dependent Variable: Similarity		Area		Distance		Absolute Distance		Starting Point	
	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b
Verbal IQ	.20(1)	.58	.15(1)	-.45	.00(1)*	-.12	.17(1)	-.40	.15(1)	-.38
Early Vision	.10(2)	.30	--	--	--	--	.09(2)	-.36	--	--
Physical Activity (0-2yrs)	--	--	--	--	.11(2)	.49	.13(3)	-.42	--	--
Physical Activity (2-5yrs)	.05(3)	-.36	--	--	.05(2)	-.50	.11(2)	.53	--	--
Physical Activity (5-16yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (0-2yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (2-5yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (5-16yrs)	--	--	--	--	.10(2)	.35	--	--	--	--
Manipulative Activity (5-16yrs)	--	--	--	--	--	--	--	--	--	--
Adult Stimulation	--	--	--	--	--	--	--	--	--	--
Number of Siblings	.09(3)	.33	.11(2)	-.34	--	--	--	--	--	--
R^2	.44		.26		.26		.50		.15	
Adjusted R^2	.26		.03		.17		.34		0	

1. Number in parentheses indicates step of the regression solution on which the predictor variable was entered.

* Non-significant r^2 of verbal IQ on step 1

Table 10. Significant Contributions to the Amount of Variance Accounted for (ΔR^2) and Standardized Regression Coefficients (b) of Predictor Variables for Each Dependent Variable on the Familiar-Complex Locomotor Path

Predictor Variable	Dependent Variable: Similarity		Area		Distance		Absolute Distance		Starting Point	
	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b	ΔR^2(Step)[1]	b
Verbal IQ	.22(1)	.54	.20(1)	-.46	.01(1)*	.05	.20(1)	-.51	--	--
Early Vision	--	--	--	--	--	--	--	--	--	--
Physical Activity (0-2yrs)	.09(3)	.35	--	--	.11(2)	.49	.11(2)	-.43	--	--
Physical Activity (2-5yrs)	.05(3)	-.38	--	--	.05(2)	.38	.10(3)	.46	--	--
Physical Activity (5-16yrs)	--	--	--	--	.11(2)	-.45	--	--	--	--
Environmental Variety (0-2yrs)	--	--	.08(2)	.29	--	--	--	--	--	--
Environmental Variety (2-5yrs)	--	--	--	--	--	--	--	--	--	--
Environmental Variety (5-16yrs)	--	--	--	--	--	--	--	--	--	--
Manipulative Activity (5-16yrs)	--	--	.07(2)	-.28	--	--	--	--	--	--
Adult Stimulation	--	--	--	--	--	--	--	--	--	--
Number of Siblings	.12(2)	.38	--	--	--	--	.10(4)	-.36	--	--
R^2	.48		.35		.28		.51		--	
Adjusted R^2	.32		.15		.05		.36		--	

1. Number in parentheses indicates step of the regression solution on which the predictor variable was entered.

* Non-significant r^2 of verbal IQ on step 1

accounting for a ΔR^2 of .10, $F(1,30)=4.82$, $p < .05$. The combination of physical activity from 0-2 years and from 2-5 years accounted for a ΔR^2 of .14 on step 3 of the solution for mean similarity, $F(2,29)=3.92$, $p < .05$. Number of siblings was a significant predictor of mean similarity on step 2 ($\Delta R^2=.12$), $F(1,31)=5.59$, $p < .05$, and of mean absolute distance on step 4 ($\Delta R^2=.10$), $F(1,29)=5.89$, $p < .05$. Finally, a significant ΔR^2 of .15 was obtained on step 2 of the solution for mean area when environmental variety from 0-2 years and manipulative activity from 5-16 years were entered, $f(2,30)=3.63$, $p < .05$.

Transfer scores. Eight transfer scores were computed for the locomotor path task similarity, area, absolute distance, and starting point error on simple and complex paths. The scores reflected the difference between measures on the novel and familiar paths. As noted in the analysis of variance results, the novelty effect was significant only for the sighted and blindfolded sighted subjects on the mean similarity measure and for all subjects on the mean area measure. Thus, evidence for an appreciable amount of transfer was generally lacking.

Regression analyses of these measures revealed only one significant predictor of performance. On the simple path, physical activity from 2-5 years accounted for a significant ΔR^2 of .12 on step 2 of the solution for similarity, $F(1,31)=4.40$, $p < .05$. However, this can be considered a random effect since it was the only significant prediction out of 88 possible predictions.

Overall, performance on the locomotor path task was predicted primarily by verbal IQ, number of siblings and physical activity from 0-2 years and from 2-5 years. In contrast to its role in the

prediction of tactual path learning performance, early vision was conspicuously absent in the prediction equations for the locomotor path task. Transfer between the tactual and locomotor tasks was essentially lacking and significant prediction of the transfer that did occur was not obtained.

DISCUSSION

Many issues were studied in the present research project. Although an integrated discussion of all the issues is academically appealing, I have chosen to discuss those which are most central to the focus of the project under somewhat discrete headings with the hope that the resulting clarity will enhance the reader's understanding of the material presented.

Efficacy of Blind Spatial Functioning

An issue raised by Warren (1977) questions the appropriateness of comparing the performance of blindfolded sighted and blind individuals. What can be said about the effects of blindness on tactual performance when the performance of blindfolded sighted subjects is used as a "control" level? In the absence of years of tactual practice by the blindfolded sighted subjects, conclusive statements cannot be made. The blind subjects may perform worse because the blindfolded sighted subjects are "visualizing," or perform better because they have had more practice. Sensory compensation, in the form of lowered threshholds or exceptional perceptual abilities, cannot be assumed to accompany blindness per se until appropriate training and practice studies are conducted with blindfolded sighted individuals.

In the present research the blindfolded sighted and the adventitiously blind groups were statistically equivalent on all measures except trials to criterion in the complex tactual path learning tasks,

where the blindfolded sighted group required significantly fewer trials to learn the path than the adventitiously blind group. However, when compared to the congenitally blind group, the blindfolded sighted group performed significantly better on all but one of the dependent measures from the tactual path learning task, but were statistically equivalent on all but one dependent measure from the pattern discrimination and locomotor path tasks. Although interesting and fitting the classic pattern in the literature, these results cannot be meaningfully interpreted because of the uncertain effects of lack of practice by the sighted and novelty of the blind experience with blindfolding.

As noted in the introduction, the more meaningful comparisons are between blind and sighted groups and between blind groups with varying visual histories. An important question is whether the spatial functioning of the blind is as efficacious as that of the sighted when both are functioning in their normal manner. Under normal circumstances, sighted individuals have visual as well as all other modes of information available for their spatial behavior while blind individuals have all except visual modes of information available for their spatial behavior. In order to explore the efficacy of blind spatial functioning, performance differences between the sighted and blind groups on the various spatial tasks can be examined. On the pattern discrimination task the sighted demonstrated greater sensitivity for pattern differences and a higher response threshold than either of the blind groups on both the simple and complex tasks (see figure 3). This means that the sighted subjects made more hit responses and also fewer false alarm responses. Thus, the use of vision by the

sighted produced better processing of information about patterns and their comparison than the use of tactual perception by the blind.

The sighted also performed better on the tactual path learning task. However, the differences were much greater between the congenitally blind and the sighted than between the adventitiously blind and the sighted. Superior performance by the sighted relative to the congenitally blind subjects on the simple and complex paths was significant on 6 of the 9 dependent measures obtained on each path. On the other hand, the sighted group's performance was significantly better than the adventitiously blind group's performance only on the dependent measure trials to criterion for both simple and complex paths and on the dependent variable overall area for the complex path. Thus, it can be said that the tactual performance of the adventitiously blind is nearly as effective as the visual performance of the sighted, while the tactual performance of the congenitally blind is markedly inferior to visual performance on this path learning task.

A similar result occurred in the locomotor path task where the adventitiously blind group performed significantly worse than the sighted on only 1 of 5 performance measures (area) from both the simple and complex paths whereas the congenitally blind group performed worse on 4 of 5 dependent measures from the simple paths and 3 of 5 dependent measures from the complex paths. Again, the results indicate that the adventitiously blind have developed spatial abilities which are more comparable to the visual abilities of the sighted than the spatial abilities developed by the congenitally blind, but this time in a far-space task.

The finding that visual functioning is superior to tactual functioning by congenitally blind subjects on near-space tasks is consistent with the only previous study of sighted and blind spatial functioning. O'Conner and Hermelin (1975) found that sighted adolescents performed a mental shape combination task better than a group of congenitally blind adolescents, substantiating the frequent assumption that visual spatial functioning is more effective than tactual spatial functioning.

Tactual Pattern Discrimination

The congenitally blind subjects correctly identified an average of 72% of the discrimination pairs in the pattern discrimination task. Their overall performance in this task was somewhat lower than that of the adventitiously blind (80%), the blindfolded sighted (79%) and the sighted (94%). Examination of figure 3 indicates that poor overall performance by congenitally blind subjects relative to their adventitiously blind counterparts was due to a significantly lower tactual sensitivity (d') for pattern differences and not to a higher response threshold. In fact, the response threshold of the congenitally blind subjects was lower than that of the adventitiously blind subjects, although this difference was not significant. This result suggests that the congenitally blind subjects were less sensitive to pattern differences and less cautious in their judgments of pattern differences.

There was also some indication in the multiple regression analysis that blind subjects with more early visual experience adopted

a more cautious response criterion in the complex pattern discrimination task, but not in the simple pattern discrimination task. Thus, although amount of early vision was a significant predictors of sensitivity to pattern differences in both the simple and complex discriminations, it predicted response criterion placement only in the complex discriminations.

Lower discrimination performance by the congenitally blind relative to the adventitiously blind is consonant with previous findings (Axelrod, 1959; Sylvester, 1913; Worchel, 1951; Drever, 1955; Cleaves & Royal, 1976). The fact that this difference reflects primarily a difference in discrimination sensitivity and not in response bias suggests that the effect of early vision may be to enhance the ability to perceive and manipulate spatial information for comparison purposes. This comparison process is probably a central phenomenon and therefore involves memory as well as other cognitive abilities. However, even when the effects of verbal IQ are partialled out, the amount of early vision remains a significant predictor of sensitivity in both simple and complex discrimination tasks.

If spatial memory is improved with visual experience, then the early blind subjects may be performing worse because they simply can't remember the first stimulus while they are examining the second. The best test of this possibility would be a comparison of performance under successive and simultaneous exposure conditions. Unfortunately, a study of this nature is not available in the literature. In related studies by Millar (1974, 1975, 1976) blind children were found to have movement representations in memory which were primarily

sequential, whereas their sighted counterparts organized memory movements in terms of a spatial array. Haptic spatial representations used by the blind children were subject to decay effects whereas the visual representations of the blindfolded sighted subjects were not. The relevance of these findings to the present discussion is that if the later blind subjects are using visual representations of the first pattern in the pattern discrimination task, their superior performance could be due to a more enduring memory representation rather than to better perceptual acuity.

Overall and Final Tactual Path Learning Performance

The patterns of results for the overall and final performance measures from the tactual path learning task were very similar. Comparisons between the sighted and the congenitally blind groups yielded identical differences on all measures except the absolute distance measure, where the sighted group was significantly better than the congenitally blind group on overall absolute distance, but equal on final absolute distance. Similarly, comparisons between the sighted and adventitiously blind groups yielded a pattern of differences on the overall measures which was identical to the pattern of differences found on the final measures, except that the sighted group was significantly better on overall area but equal on final area.

The multiple regression analysis of blind tactual path learning contained mixed evidence for a difference between overall and final performance. On the simple path, early vision equally predicted overall and final performance measures, but was more predictive of

overall relative to final performance on the complex paths. The 3 developmental physical activity scales were also more predictive of overall performance relative to final performance on both simple and complex tasks, although this difference was more pronounced on the complex paths.

These differences in the patterns of results for the overall and final performance measures suggest at least 2 trends. First, it is evident that prediction of final performance is poor relative to overall performance. This could result if performance variability is reduced in the final measures, thus decreasing correlation and prediction. Inspection of figures 5, 6 and 8 suggests that this decrease in variability may be the case for area since the separation of the two blind groups is somewhat reduced in measures of final performance, but probably not for absolute distance. The second trend in these results is a tendency for the reduction in prediction or group differences associated with final performance relative to overall performance to occur primarily on the complex path. This latter trend is contrary to predications that might be made on the basis of the hypothesis that early vision is primarily important to spatial performance in relatively difficult or complex tasks. On the basis of that hypothesis, one would expect persons with less visual experience to be more likely to achieve a final level of performance comparable to that of persons with more visual experience in a simple task than in a complex task. However, precisely the opposite occurred.

In total, the evidence for a real difference between overall and final performance was weak. Further, the two measures were not

independent since the overall measures included data from the final two trials. Therefore, tactual path learning performance in the following discussions will include both overall and final measures without further effort to differentiate them.

The Effect of Task Complexity

It was predicted that early vision might impart an advantage to the adventitiously blind only when task demands were great. This would be evidenced by a significant group by complexity interaction with simple effects showing the adventitiously blind better on the complex tasks but approximately equal on the simple tasks to the congenitally blind. This prediction was not supported in any of the three experimental tasks. The adventitiously blind demonstrated a level of tactual sensitivity on the discrimination task which was uniformly better than that of the congenitally blind across complexity conditions. However, this pattern of results may have been due to the choice of a simple task which was complex enough to differentiate the 2 groups of subjects.

On the tactual path learning task, the adventitiously blind performed better than the congenitally blind, but this difference actually occurred less frequently on the complex paths (4 of 9 dependent variables) than on the simple paths (5 of 9 dependent variables). The result was supported by the multiple regression analysis where early vision was a significant predictor of performance on 7 of 9 dependent variables on the simple paths and on only 5 of 9 dependent variables

on the complex paths. While these differences are too small to warrant the conclusion that early vision is a more important determinant of performance on the simple tasks than on the complex tasks, they definitely indicate that the adventitiously blind did not have the advantage only on the complex tasks.

The two blind groups performed equivalently on the locomotor path task as measured by all dependent variables on the complex paths and by all dependent variables except absolute distance on the simple paths. Again, there was no support for the hypothesis that complex tasks would differentiate the 2 blind groups more than simple tasks. However, it is impossible to know exactly where on the complexity dimension the tasks used in this study were located. It is possible that they were too simple or too complex or too similar in level of complexity to show differential effects.

Hypotheses of Spatial-perceptual Development

The two hypotheses proposed to account for deficits in blind spatial functioning identified early visual experience (Warren, 1977) and early perceptual-motor experience (Jones, 1975) as the important determinants of spatial performance. The present research provided a test of these two hypotheses by determining the amounts of several classes of experience and relating these measures to spatial performance in a multiple regression analysis. Although the multiple regression approach can often yield illuminating results, it usually requires a large number of subjects to obtain reliable results. A

conservative minimum value for the ratio number of subjects to number of predictor variables is 10:1 (Kerlinger and Pedhazur, 1973). In some research, however, obtaining this minimum ratio is not practical and corrections for shrinkage in the total proportion of variance accounted for (R^2) by a set of predictors must be calculated.

There have been several procedures suggested for adjusting R^2 and a recent study by Carter (in press) recommends that adjustments should be derived using the Wherry (1940) formula when R^2 is less than .60 and the formula suggested by Olkin and Pratt (1958) when R^2 is greater than .60. Absolute and adjusted R^2s calculated according to Carter's recommendations are given in Tables 2 to 10 for each dependent variable which was significantly predicted by at least one predictor variable. It should be emphasized that the adjusted R^2s are very conservative estimates since they are based on the total possible number of predictors (11), whereas the unadjusted R^2s include only significant subsets of the possible predictors (1-7 in number). In most cases the loss in prediction is moderate and should not affect interpretation of the results. The results, however, are based on the unadjusted R^2s and the reader should be aware that they contain a degree of unreliability which is somewhat greater than one would desire under optimal research conditions. In general, discussion of the multiple regression results will not include further reference to the problem of shrinkage.

Returning to the interpretation of the multiple regression results as they relate to the two hypotheses about the origins of blind spatial deficits, it is clear that the predictive validity of the experience variables depends somewhat upon task characteristics. The

importance of early vision as a predictor of performance was most apparent in the tactual pattern discrimination and tactual path learning tasks. However, early vision was significantly predictive of locomotor performance only on the familiar-simple path as measured by similarity and absolute distance. The remaining 3 criterion variables on this path were not predicted by early vision and not one of the 5 criterion variables measured on the other 3 locomotor paths was predicted by early vision. These results were supported by the analysis of variance results which showed that the adventitiously blind subjects performed better as a group than the congenitally blind subjects on the tactual tasks but that the two blind groups showed similar performance on the locomotor path task.

These task-related differences in the predictive validity of early vision are consistent with previous research showing improvement on near-space tasks with visual experience but not on far-space tasks (see Warren et al., 1973, for a review). In the introduction it was hypothesized that there may be a basic spatial-perceptual system in all individuals and that early vision acts in some way to enhance the efficiency of the system for tactual near-space functions whereas its efficiency for far-space functions develops normally and is adequate even in congenitally blind individuals. This hypothesis cannot be rejected on the basis of the present results. The congenitally blind group showed deficits on near-space tasks relative to the adventitiously blind group, but performed as well as the adventitiously blind group on the far-space task.

A possible explanation of the discrepancy in spatial performance by early blind subjects on near- and far-space tasks is that far-space information lends itself more readily to verbal mediation and that verbal access to the spatial-perceptual system is more efficient. If this is the case, one would expect verbal IQ to predict far-space performance more accurately than it does near-space performance. This expectation was not borne out in the multiple regression analysis. Verbal IQ was a significant predictor of 12 of 20 tactual performance variables and 13 of 20 locomotor performance variables. The ranges of r^2s and standardized regression coefficients associated with verbal IQ were .12 to .25 and .23 to .52, respectively, for the tactual performance variables and .15 to .25 and .37 to .58, respectively, for the locomotor performance variables. Thus, verbal IQ was approximately equally predictive of the two kinds of spatial performance. The results suggest that verbal mediation is probably not related to the difference between near- and far-space functioning in the early blind. The lack of visual experience in these subjects is apparently related to an actual spatial-perceptual deficit that specifically affects near-space functioning.

In addition to early vision, some of the early perceptual-motor experience variables were predictive of spatial performance in the various tasks. However, among those not predictive of performance were the environmental variety scales for all age periods, the adult stimulation scale and the manipulative activity from 5-16 years scale. Speculations about the absence of performance prediction by these

independent variables can be explored, but their tentative nature should be emphasized. For example, the environmental variety scales included some items such as number of days spent hiking which involved active behaviors by the respondents, but most of the items were designed to measure the availability of varied environmental stimulation. Thus, there was no assurance that the subjects scoring high on these scales actually interacted with a greater variety of environments or received a greater quantity of environmental stimulation. The importance of active behavior in the presence of stimulation to the development of adequate perceptual motor skills is well documented and the lack of predictive validity of the environmental variability scales to criterion measures selected to reflect the degree of development in a spatial-perceptual system is not surprising. However, the physical activity scales (discussed below) included primarily measures of active interaction with the environment and were found to be consistently related to the criterion measures.

Regarding the lack of prediction by the manipulative activity from 5-16 years scale, recall that the reliabilities of the manipulative activity scales for the 2 youngest age periods were not high enough to warrent use of the scales in the present study. However, the reliabilities of the manipulative activity scales for the age periods 5 to 10 years and 10 to 16 years were acceptable and the average of those 2 scale scores was used as a measure of manipulative activity from 5-16 years in the regression solutions. The lack of significant prediction of spatial performance by this independent

measure may reflect unimportance of this type of experience in general, unimportance of this type of experience for the 5 to 16 year age period, or the inability of the scale to measure "manipulative activity." There is currently no basis for choosing among these alternatives, although consideration of the problems with this scale in general suggests a measurement problem. In any case, adequate measures of this type of activity need to be developed for the 0 to 5 year age period and refined for the later age periods. Prior to the development of these improvements, meaningful analysis of the importance of this type of activity for the development of spatial skills cannot be pursued.

The last independent variable that failed to predict performance was the adult stimulation scale. This scale was devised to measure the degree to which adults in the subject's life were available to the child. It included items such as the amount of time the father was home and the amount of time each parent spent interacting with the child. Again, this scale included some active items and some passive ones, and it might be that a scale measuring only active interactions with adults would be more highly predictive of performance. This is another issue that should be explored in future research. As a measure of social contact, the variable and its study have implications for the structuring of family and institutional settings.

The remaining independent variables included the physical activity scales from three age periods and number of siblings, which were consistently related to performance on at least one of the tasks. It is interesting that number of siblings, which was selected as a measure of social interaction in the same way that the adult

stimulation scale was selected, was a fairly consistent predictor of performance in the locomotor path task and an occasional predictor of tactual path learning performance. In every regression solution that included number of siblings as a significant predictor, the regression coefficient associated with number of siblings indicated that subjects with more siblings performed better than subjects with fewer siblings. It is especially likely in blind children, who depend largely on others for guidance and mobility, that the presence of other children in the home is a major determinant of the degree to which they engage their environment in active play. The fact that a blind child can follow around and play with several brothers and sisters all day is apparently important to the development of both tactual and locomotor spatial skills, but information about the relevant age periods for this experience is not available in the present study.

On the other hand, the regression coefficients for the physical activity scales suggest very clearly that the age at which the experience occurs is very important. The most consistent predictor of tactual path learning performance was physical activity from 2 to 5 years of age. It was included in 6 of 7 equations predicting performance on the simple paths (overall and final distance errors were not included as measures of performance since they involved both the direction and magnitude of error) and 3 of 7 prediction equations for the complex paths. In every equation the regression coefficient of this predictor indicated a negative relationship between performance and degree of activity: the individuals who were more active during this age period performed worse on the tactual path learning task than

those who were less active. A similar relationship appeared in the locomotor path task. Physical activity from 2 to 5 years was included in 7 of 16 prediction equations (excluding the 4 prediction equations for distance errors) and in every case was negatively related to performance.

The basis for the negative relationship between physical activity from 2 to 5 years of age and spatial performance is not clear, but speculations can be entertained. It seems reasonable, for example, that some aspect of development is occurring during that particular age period which is somehow inhibited or pre-empted by gross physical activity. Piaget (1969; 1971; Ginsburg and Opper, 1969) has described the child of 2 to 5 years as one who is just discovering symbols and their use in cognitive activities. He describes the period as stage 1 of pre-operational thought in which the child is beginning to form mental images or representations of perceptions, but has not fully developed the ability to use symbolic functions. As a result, the child focuses on relatively concrete objects and events to be represented and generally forms only representations which are static and do not incorporate change or relationships to other representations separated in space or time. Perhaps the child who is physically very active during this period does not engage in the formation and manipulation of mental representations to the extent which is necessary for optimal development of a spatial reference system.

According to this reasoning, the establishment of the spatial reference system depends somewhat upon intellectual or cognitive

development being "on time." If a child is late in developing the symbolic cognitive functions, the benefit which his spatial reference system receives is limited. This hypothesis assumes that the spatial reference system is maturing somewhat independently of the cognitive system, although if maturation of the two systems is sufficiently coordinated the level of development within each system is likely to be affected by the level of development in the other. On the other hand, the development of the spatial reference system is not so firmly established by the age of 5 years that specific types of activities which occur later have no effect on the development of spatial skills. In fact, physical activity from 5-16 years was predictive of 4 of 14 performance measures on the tactual path learning tasks in the present research. In order to substantiate these speculations about the relationship between physical activity between 2 and 5 years of age and the development of a spatial-perceptual system, a replication of the finding that a negative relationship exists between these 2 variables in the blind population is necessary. The theoretical and practical benefits associated with further study in this area are well worth the attention of researchers.

It is possible that the relationship is specific to the blind population. Generality could be assumed, however, if a similar relationship was found to exist between physical activity between 2 and 5 years and spatial performance in the sighted or blindfolded sighted groups used in this study. The number of subjects in each of these two groups (20) was too small to allow multiple regression analysis of performance comparable to that used for the blind subjects and

the fact that the two groups performed essentially different tasks--one visual and the other tactual--precluded combining the two groups for a multiple regression analysis. However, simple correlations are available and inspection of these suggests that such a relationship does not exist for sighted subjects performing with vision. It is possible, though, that the use of vision so completely changes the task that a relationship between performance and physical activity from 2-5 years could not really be expected.

There is, however, some indication that locomotor spatial performance by blindfolded sighted subjects is negatively related to physical activity from 2 to 5 years. For this group of subjects physical activity from 2 to 5 years was correlated -.30 or lower with 11 of 16 performance measures and 7 of these correlations were significant at the .05 level with N equal to 18 (physical activity scale scores were unavailable for 2 subjects whose parents failed to return part 2 of the early experience questionnaire). Contrary to the evidence for a negative relationship in the locomotor path task, 3 of 14 performance measures in the tactual path learning task were correlated .30 or higher with physical activity between 2 and 5 years, indicating a positive relationship between the two variables. None of the tactual path learning performance measures was correlated less than -.07 with this predictor variable, a fact which lends no support to the notion that tactual spatial performance in blindfolded sighted subjects may be negatively related to physical activity from 2-5 years. It is clear in the foregoing discussion that conclusive evidence for such a relationship is not available. Further, the theoretical and practical

importance of clarifying the relationship in blindfolded sighted subjects is questionable, since the condition of blindfolding is extremely unnatural.

In contrast to the negative relationship between physical activity from 2-5 years and the spatial performance of the blind subjects, physical activity from 0-2 years and from 5-16 years was positively related to both tactual and locomotor performance, although significant predictions were not obtained for all performance measuress. Tactual pattern discrimination performance was less consistently related to the predictor measures.

Physical activity from 0-2 years was found to be a significant predictor of locomotor performance on 4 of 16 performance measures in the multiple regression analysis. It was also a significant predictor of tactual path learning, where 6 of 14 performance measures were significantly related to it. The regression coefficients indicated a positive relationship for all measures. In contrast to these results, physical activity from 0-2 years was not predictive of either d' or β in the tactual pattern discrimination task.

Evidence for a positive relationship between physical activity from 5-16 years and spatial performance was not as strong as that for physical activity from 0-2 years, but was present in the results of the multiple regression analysis. Physical activity from 5-16 years significantly predicted only 1 of 16 measures of locomotor performance and 4 of 14 measures of tactual path learning performance. Again, the regression coefficients indicated a positive relationship between

performance and physical activity from 5-16 years.

On the complex tactual pattern discrimination task, both d' and β were negatively predicted by physical activity from 5-16 years. On the other hand, predictions of d' and β on the simple discrimination task by this independent variable were not obtained.

The above results suggest that blind persons who were more active during the age periods 0-2 and 5-16 years performed better on both the tactual path learning and the locomotor path tasks. This observed relationship between physical activity and spatial performance is consistent with the hypothesis that organism-environment interactions are important to the development of the spatial-perceptual system. However, when the multiple regression results are considered in their entirety, the suggestion by Jones (1975) that motoric interaction with the environment is the primary determinant in spatial development received only partial support.

Specifically, although the various measures of active involvement with the environment such as the physcial activity scales and the number of siblings were predictive of performance in both the tactual path learning task and the locomotor path task, the single best predictor of tactual path learning performance was early vision. Early vision was the single best predictor of 8 of 12 performance variables on the tactual path learning task that were predicted by any of the experience measures. Physcial activity from 2-5 years was the single best predictor in 3 of the remaining 4 performance variables, but the regression coefficients indicated a negative relationship whereas Jones would have predicted a positive one.

In an attempt to corroborate this result, performance IQ was treated as a measure of tactual spatial ability by regressing it as a dependent variable on the early experience variables. After verbal IQ was entered into the equation on step 1 of the solution, early vision was the single best predictor of performance IQ, accounting for a ΔR^2 of .17 on s-ep 2, $F(1,32) = 9.42$, $p < .01$. Thus, early vision was more strongly related to this standardized and validated measure of spatial performance than any of the other early experience variables. Corroborating evidence from the tactual pattern discrimination task was not as strong. Discrimination sensitivity was best predicted by early vision on the simple but not the complex task, where manipulative activity from 5-16 years was the single best predictor.

In contrast to early vision's role as the single best predictor of tactual path learning performance and performance IQ, it was only the best predictor of 2 of 11 locomotor path performance measures that were predicted by any of the early experience measures. On the other hand, number of siblings was the single best predictor of 6 of the 11 locomotor performance measures. If this measure reflects the degree to which the blind subjects were interacting with their siblings, its high predictive validity would suggest a very important role for this kind of experience in the development of locomotor or far-space abilities. Other single best predictors of locomotor path performances included environmental variety from 0-2 years, physical activity from 0-2 years and physical activity from 2-5 years.

The difference between the prediction of near-space performance and the prediction of far-space performance suggests several conclusions.

First, the presence of early vision is of prime importance in the development of tactual spatial skills, as predicted on the basis of a suggestion by Warren (1977). It is also noteworthy that non-visual early experience variables such as physical activity and the number of siblings were predictive of tactual spatial skills in addition to the predictions attributable to early vision. Therefore motoric interaction with the environment is a factor in the development of a spatial-perceptual system underlying tactual spatial performance, but does not enjoy the exclusive role hypothesized by Jones (1975). However, it is the primary, if not the exclusive, factor of those studied which influences the development of a spatial-perceptual system underlying locomotor spatial performance. The question of whether there is a single spatial-perceptual system underlying both near- and far-space abilities was not directly addressed in the present research, but the results suggest separate systems.

Although both hypotheses regarding the development of spatial perception in blind individuals are at least partially correct in identifying the important variables, their common suggestion that these variables act primarily upon intermodality integration was not supported in the results of the present study. In fact, there were no differences between the congenitally blind and adventitiously blind groups on any of the 4 transfer scores on either the simple or complex locomotor paths. Further, the transfer scores were not related to any of the predictor variables, including verbal IQ, in spite of considerable variability in transfer among the blind subjects. However, the mean transfer scores were very nearly zero for the blind subjects, a fact

which indicated that transfer may not have occurred for any subjects due to the nature of the task. If this is true, then the variability in transfer scores reflects only the differences between random errors on the novel and familiar paths. In view of this conspicuous lack of transfer, which also occurred in sighted and blindfolded subjects, the conclusion that the task was an inappropriate test of intermodality integration is the most tenable interpretation.

Current Experience Variables

The possibility that current activities and experiences can influence the spatial functioning of an individual has both practical and theoretical implications. On the practical side, if an individual's spatial functioning is impaired due to perceptual or perceptual-motor deprivation it would be important to educators working in the area of remediation to know whether current experiences can act in some way to compensate for the developmental retardation in spatial ability. It would also be valuable to know generally what types of behaviors or experiences could be expected to lead to the improvement of spatial abilities and what types might be expected to contribute very little to or even interfere with that improvement. The theoretical issue of whether or not development of spatial abilities is dependent upon specific experiences occurring during specific critical age periods is also addressed in the study of the effect of current experience on spatial abilities. If prediction of spatial performance by current experiences exceeds prediction by early experiences, one would conclude that at least some degree of compensation is possible. If compensation

is possible, it would suggest that a certain degree of flexibility remains in the spatial-perceptual system even into adulthood.

In order to examine the relationship between current experiences and spatial performance a second set of multiple regression analyses of the dependent variables was conducted. It should be emphasized that the secondary nature of this analysis qualifies it somewhat, and the results should be considered preliminary at this time. It was originally hoped that current experience variables could be included in the primary analysis, but for reasons stated earlier, the primary analysis was restricted to the developmental measures of early experience.

The secondary multiple regression analysis involved entering verbal IQ and all the significant early experience predictors of a given dependent variable into the regression equation on step one of the solutions. This was done in order to control for variation in the current experiences of subjects that might be attributable to developmental variables. Following the partialling of the early experience predictors on step 1 of the solution, a stepwise regression solution of each dependent variable on the 4 current experience scale scores--physical activity, environmental variety, social contact and sedentary activities--was carried out. Significant predictors or combinations of predictors were thus determined.

The only convincing result from this analysis was a significant increase in prediction of all 4 locomotor performance variables on the novel-simple path by the environmental variety scale. For each dependent variable, the regression coefficient indicated a positive

relationship between performance and current environmental variety scores. This scale also significantly increased prediction of 1 of 4 locomotor performance measures (area) on the familiar-simple path, but none of the performance measures on either of the complex locomotor paths. The only significant current experience predictors of performance on the tactual path learning task were physical activity and sedentary activity. These 2 independent variables combined on step 2 of the solutions for final area and absolute distance from the simple path and produced significant increases in prediction. The regression coefficients indicated a negative relationship between performance and sedentary activity and a positive relationship between performance and physical activity in these blind subjects. No other predictions of tactual path learning performance by the current experience variables were revealed. Current environmental variety also significantly increased the prediction of both d' and β from the complex tactual pattern discrimination task.

In general, the above analysis indicates that current experiences are not predictive of spatial performance when the correlation of performance with early developmental variables is partialled out. Social stimulation, which as a developmental variable was a fairly consistent predictor of locomotor performance, failed to account for significant increases in the prediction of any of the performance variables when measured as a current experience. Similarly, physical activity, which as a developmental variable was highly predictive of both tactual path learning and locomotor path performance, was a very weak predictor of

both tactual path learning and locomotor path performance when measured as a current experience. Sedentary activity was also a weak predictor as a measure of current experience and was not measured as a developmental variable. Environmental variety was somewhat more predictive of performance, but the pattern of results was inexplicable.

Accounting for Individual Differences

The need to determine and account for individual differences in spatial performance has been promoted by Warren (1977). The use of the early experience questionnaire, although preliminary in the present study, allowed the identification of aspects of past experience which reliably predicted individual spatial performance. While some individual variation in performance remained unaccounted for by the measures of early experience, it is noteworthy that significant amounts of individual differences in performances were attributed to variation in experience.

The importance of identifying causal relationships between spatial performance and early experience is obvious. From a practical viewpoint, identification of the causes of individual differences in spatial performance would have profound effects on educational and training programs designed to promote the acquisition of spatial concepts and skills in blind persons. Also, the study of perceptual development would benefit from the development of theoretical models of the development and acquisition of spatial skills.

Based on results of the present research and other research on

blind spatial functioning, causal models could be hypothesized and tested. However, prior to the testing of such models, refinement of the questionnaire is needed. It was developed and initially used in this study and the reliabilities of subscales were in some cases only minimally acceptable. Also, the appropriateness of items was largely assumed on the basis of forethought and subsequent acceptable reliability. Thus, it is clear that refinement and validation of the subscales are necessary. It should be emphasized, however, that the questionnaire approach was successful in the present study and should continue to be applied to research problems where alternative methods are impossible or impractical.

SUMMARY OF FINDINGS

The research project described in this paper yielded the following findings regarding blind spatial functioning:

1. Adventitiously blind subjects performed as well as blindfolded sighted subjects on all tasks. However, their performance was somewhat worse on all tasks than that of sighted subjects performing with vision.

2. Congenitally blind subjects performed worse than blindfolded sighted subjects on the tactual path learning task, but the 2 groups performed similarly on the tactual pattern discrimination and locomotor path tasks. Sighted subjects using their vision performed better than the congenitally blind subjects on all tasks.

3. Adventitiously blind subjects performed better on the tactual pattern discrimination and tactual path learning tasks than congenitally blind subjects, but the two groups were equivalent on the locomotor path task.

4. Differences between congenitally blind subjects' performance and adventitiously blind subjects' performance on the tactual pattern discrimination task were due to greater discrimination sensitivity in the adventitiously blind subjects rather than to a more lenient response criterion.

5. The pattern of results on the overall performance measures from the tactual path learning task was similar to the pattern of results on the final performance measures.

6. On the basis of prior research, the adventitiously blind group was predicted to perform better than the congenitally blind group on

the complex tasks but not on the simple tasks, but this pattern of results did not occur. The levels of complexity used may have been inappropriate to obtian the predicted results.

7. Early vision was a very good predictor of blind spatial performance on the tactual pattern discrimination and path learning tasks, but not on the locomotor path task. Verbally mediated performance on the locomotor task was ruled out as an explanation for the absence of prediction by early vision.

8. Physical activity measures from 0-2 years and from 5-16 years were positively related to performance on the tactual path learning and locomotor path tasks, while physical activity from 2-5 years showed a consistent negative relationship to performance on these tasks. Speculations about this negative relationship were discussed.

9. Number of siblings was positively related to performance on both the tactual path learning and locomotor path tasks.

10. The pattern of results from the multiple regression analysis suggested that near-space performance was primarily related to amount of visual experience, whereas far-space performance was primarily related to non-visual early experience, especially physical activity and sibling contact.

11. In general, current levels of experience did not significantly increase prediction of performance beyond that obtained with the developmental measures of experience.

12. The early experience questionnaire successfully provided information which predicted individual performance on the spatial tasks. Its refinement and continued application to research problems would seem profitable at this time.

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APPENDIX A: PRELIMINARY EARLY EXPERIENCE QUESTIONNAIRE

EARLY EXPERIENCE QUESTIONNAIRE - PART I

This questionnaire is designed to provide information about your past and present experiences. Confidentiality of all information is guaranteed. Items in the first part are to be completed by you, while those in the second part should be completed by a parent or guardian with whom you lived as a child. It is very important that all items in each part be completed. It is also very important that the first part be completed by you alone and the second part be completed only by a parent or guardian with whom you were reared. Two stamped envelopes are provided for you to mail the second part to the parent or guardian and for them to return it to you, if mailing is necessary. Your cooperation in providing accurate information is greatly appreciated since the results of this questionnaire will be used to design enrichment programs for blind and other handicapped children. Again, answer all items. If additional space is required for any item, you may use the back of the page.

If you have any questions, contact Terry Schmitt in LS-2450C (phone: 686-7140) or Dr. David Warren in LS-2427 (phone: 787-5732). When both parts of the questionnaire are complete, bring it to Terry Schmitt in LS-2450C or to class on Monday, November 1 and you will receive $5 and 1 hour of research participation credit for Introductory Psychology (10A).

---

1. Name:_____ 4. Date:_____

2. Address:_____ 5. Birthdate:_____

_____ 6. Sex: M F

3. Phone:_____

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7. How many brothers do you have?_____ Present ages(yrs)_____

8. How many sisters do you have?_____ Present ages(Yrs)_____

9. Do you live...
   - ____with parent or guardian?
   - ____alone?
   - ____with one other person?
   - ____with more than one other person?

10. Do you own a
    - ____bicycle
    - ____motorcycle
    - ____car

11. On an average night, how many hours do you sleep?_____

12. How much do you like mathematics?____none____less than most ____some____more than most____very much

13. How would you rate your overall mathematical ability? ____poor; ____below average;____average;____good;____excellent.

14. How would you rate your understanding of geometry? ____poor; ____below average;____average;____good;____excellent.

15. How many times in the past 5 years have you been out of your home state?____

16. How many different states have you visited in your lifetime?____

17. How many times in the past 5 years have you been out of the nation?____

18. How many different countries have you visited in your lifetime? ____

19. How would you rate your current overall level of physical activity? ____very inactive;____somewhat inactive;____normally active: ____somewhat overactive;____very overactive.

20. Estimate the percent (0-100%) of an average week (excluding nighttime sleep) you spend in each activity category listed below. Some activities may contribute to more than one category. For example, time spent in school or at work might be spent alone or with others, or riding a bicycle, yardwork, etc. might all occur out-of-doors and be physical work.

____% studying
____% reading for pleasure
____% drawing or painting
____% alone
____% out-of-doors
____% resting or napping
____% in school (actual class time)
____% yardwork
____% housework
____% playing team sports
____% individual sports (jogging, tennis, hiking, etc.)
____% playing a musical instrument
____% physical work
____% socializing
____% watching TV
____% listening to radio or music
____% riding a bicycle
____% driving a car
____% working with tools
____% sewing
____% other crafts
____% organized activities (clubs, church, etc.)
____% working at a job
____% with one other person
____% with more than one other person
____% playing games (cards, chess, etc.)
____% swimming
____% dancing

21. What is your visual acuity without glasses? ____

22. Are you hard of hearing? ____

23. How well can you hear? ____poor;____fair;____average;____good; ____excellent.

24. Number of years as an undergraduate student:_____

25. Number of years as a graduate student:_____

26. Highest degree you have received:_____

27. Indicate the number of times you engate in the activities listed below in an average year.

_____one day outings (beach, mountains, etc.)
_____overnight trips 5 days or less
_____overnight trips more than 5 days long
_____boating
_____hiking
_____flying in a plane
_____visiting a large city (e.g., L.A.)
_____camping
_____building something
_____riding in a train

28. How good is your sense of direction? ____poor;____fair; ____average;____good;____excellent.

29. How good is your ability to learn your way around a strange town or city? ____poor;____fair;____good;____average;____excellent.

30. How good is your grasp of spatial relationships? ____poor; ____fair;____average;____good;____excellent.

EARLY EXPERIENCE QUESTIONNAIRE - PART II

Subject's name_____

To the parent or guardian:

This questionnaire is designed to provide information concerning the childhood experiences of the person named above. It should be completed by a parent or guardian with whom the person was reared. It is also important that all items are completed and that only a parent or guardian with whom the person was reared completes them. Each item should be answered as it applies to the above-named person. If additional space is required for any item, you may use the back of the page. Your cooperation in providing accurate information is greatly appreciated, since the results of this questionnaire will be used to design enrichment programs for blind and other handicapped children.

This questionnaire is just now being developed and some additional information may be required. We therefore request the name, address and phone number of the parent or guardian so that we may obtain additional information if the need arises. We guarantee confidentiality of all information. Again, please answer all items. Thank you for your help with this important project.

Dr. David H. Warren Terry L. Schmitt
Department of Psychology
University of California, Riverside

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31. Name of parent or guardian:_____

32. Address:_____

_____

33. Phone:_____

34. Was your child's birth natural?____, or was medication used?____

35. Was the pregnancy full term?____, or premature?____. If premature, how many weeks?____

36. What was the birthweight of your child?____lbs.____oz.

37. How long did your infant stay in the hospital before going home for the first time?____days.

38. Was he/she in an incubator?_____ How long?_____

39. At what age was your child toilet trained when awake?_____; asleep?_____

40. At what age did your child begin to use language effectively?
_____

41. List all occasions when the child was hospitalized or confined to bed for at least 1 week during the first 16 years of life.

	age	length of stay	reason for stay
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

42. List any illnesses or conditions (for example, asthma, allergies, epilepsy, nervous or muscular disorders, etc.) which limited your child's physical activity.

illness or condition	age

43. Rate your child's health and estimate the number of days per year he/she was ill for each age period listed below:

age	overall health					no. days ill/yr.
0-2 years	poor	fair	average	good	excellent	
2-5 years	poor	fair	average	good	excellent	
5-10 years	poor	fair	average	good	excellent	
10-16 years	poor	fair	average	good	excellent	

44. List the number of adults (including yourself) and other children living in your immediate household during each of your child's first 16 years of life.

age:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
adults																
other children																

45. In the spaces below, give the information about each residence (in chronological order) in which you lived during the first 16 years of your child's life.

house(H) or apt (A)	no. rooms	miles from prev. res.	no. of stairs	size of yard none, S-M-L	age of child	Pop. of commu-nity	describe area (mts., desert...)

46. Estimate the overall level of physical activity of your child for each of the age periods listed below. Use the following scale: 0=very inactive; 1=somewhat inactive; 2=normally active; 3=somewhat overactive; 4=very overactive.

age:	0-6 mo.	6mo.-1yr	1-2yrs	2-5yrs	5-10yrs	10-16yrs

47. For each age period, indicate the average number of hours the child slept each night: 0-2yrs____; 2-5yrs____; 5-10yrs____; 10-16 yrs____

48. For each age period, estimate the percent (0-100%) of an average week (excluding night-time sleep) the child spent in each activity category listed below. Some activities may contribute to more than one category. For example, time spent in yardwork might be spent alone, out-of-doors, etc.

	Age Periods			
Activities	0-2yrs	2-5yrs	5-10yrs	10-16yrs
playing alone	%	%	%	%
playing with other children	%	%	%	%
lying quietly	%	%	%	%
napping	%	%	%	%
playing with toys	%	%	%	%
yardwork	%	%	%	%
housework	%	%	%	%
climbing (trees, bars, etc.)	%	%	%	%
leisure reading	%	%	%	%
drawing or painting	%	%	%	%
skilled work with hands (sewing, building models, erector sets, etc.)	%	%	%	%
Studying	%	%	%	%
in school or day-care center (with other children)	%	%	%	%

	0-2yrs	2-5yrs	5-10yrs	10-16yrs
being cared for by someone other than you	%	%	%	%
indoors	%	%	%	%
out-of-doors	%	%	%	%
working with tools	%	%	%	%
organized sports	%	%	%	%
other organized activities (scouts, clubs, etc.)	%	%	%	%
playing a musical instrument	%	%	%	%
riding tricycle or bicycle	%	%	%	%
watching TV	%	%	%	%
listening to radio or music	%	%	%	%
playing with mother	%	%	%	%
playing with father	%	%	%	%
	%	%	%	%
	%	%	%	%
	%	%	%	%

49. What percent of the child's average week (excluding sleep) was the father or male guardian at home for each age period?
0-2yrs:____%; 2-5yrs:____%; 5-10yrs:____%; 10-16yrs:____%.
mother or female guardian?
0-2yrs:____%; 2-5yrs:____%; 5-10yrs:____%; 10-16yrs:____%.

50. For each of your child's age periods, estimate the number of times per year that he/she was included in each activity below.

Activities	0-2yrs	2-5yrs	5-10yrs	10-16yrs
went to park				
played on playground equipment				
child spent night away from home				
went to zoo, museum, etc.				

	0-2yrs	2-5yrs	5-10yrs	10-16yrs
went hiking				
went to beach				
went to mountains				
other 1-day outings				
went boating				
rode in an airplane				
went camping				
overnight trips less than 5 days				
overnight trips longer than 5 days				

51. At what age did your child begin to crawl?_____months

52. At what age did your child begin to walk?_____months

53. For each of your child's age periods, estimate the economic level of your family

Age	Economic level				
0-2yrs	lowest	low	middle	high	highest
2-5yrs	lowest	low	middle	high	highest
5-10yrs	lowest	low	middle	high	highest
10-16yrs	lowest	low	middle	high	highest

54. What is the highest educational level attained by the parent(s) or guardian(s)? _____

55. Estimate your child's physical independence. Consider whether or not he/she provided own transportation, was willing to explore unknown areas, wandered off as a child, etc. Also consider your protectiveness of the child, i.e., did you always take him places; did you restrict him to room, house, or yard for fear of the child being hurt, etc.

55. (continuted)

0-2yrs:____very independent;____somewhat independent;____average;
____somewhat dependent;____very dependent.

2-5yrs:____very independent;____somewhat independent;____average;
____somewhat dependent;____very dependent.

5-10yrs:____very independent;____somewhat independent;____average;
____somewhat dependent;____very dependent.

10-16yrs:____very independent;____somewhat independent;____average;
____somewhat dependent;____very dependent.

APPENDIX B: FINAL EARLY EXPERIENCE QUESTIONNAIRE

EARLY EXPERIENCE QUESTIONNAIRE - PART I

This questionnaire is designed to provide information about your past and present experiences. Confidentiality of all information is guaranteed. Items in the first part are to be answered by you, while those in the second part should be completed by a parent or guardian with whom you lived as a child. It is very important that all items in each part be completed. It is also very important that the first part be completed by you alone and the second part be completed only by a parent or guardian with whom you were reared. Two stamped envelopes are provided for you to mail the second part to the parent or guardian and for them to return it to you, if mailing is necessary. Your cooperation in providing accurate information is greatly appreciated since the results of this questionnaire will be used to design enrichment and educational programs for blind and other handicapped children. Again, answer all items. If additional space is required for any item, you may use the back of the page.

1. Name:_____ 4. Date:_____

2. Address:_____ 5. Birthdate:_____

_____ 6. Sex: M F

3. Phone:_____

7. How many brothers do you have?____ Present ages(yrs)_____

8. How many sisters do you have?_____ Present ages(yrs):_____

9. Do you live...
   ___with parent or guardian?
   ___with someone other than your parent or guardian?
   ___alone?

10. On an average night, how many hours do you sleep?_____

11. How much do you like mathematics?___none;___less than most; ___some;___more than most;___very much.

12. How would you rate your overall mathematical ability? ___poor;___below average;___average;___above average; ___excellent.

13. How would you rate your understanding of geometry? ___poor;___below average;___average;___good;___excellent.

14. How many times within the past 5 years have you traveled more than 100 miles from your home?_____
more than 500 miles from your home?_____
more than 1,000 miles from your home?_____
more than 5,000 miles from your home?_____

15. How many different states have you visited in your lifetime?_____

16. How many different countries have you visited in your lifetime?
_____

17. How would you rate your current overall level of physical activity?
_____not al all active;____somewhat inactive;_____normally active;
_____somewhat overactive;_____very overactive.

18. Estimate the number of hours in an average week you spend in each activity category listed below. Some activities may contribute to more than one category. For example, time spent in school or at work might be spent alone or with others, or riding a bicycle, yardwork, etc. might all occur out-of-doors and be physical work.

_____studying at home
_____reading
_____drawing or painting
_____alone
_____out-of-doors
_____resting or napping
_____in school (actual class time)
_____yardwork
_____housework
_____playing team sports
_____individual sports or exercises
_____playing a musical instrument
_____physical work
_____socializing
_____listening to radio or music
_____riding a bicycle
_____driving a car
_____working with tools
_____sewing
_____other crafts
_____organized activities (clubs, church, etc.)
_____working at a job
_____with one other person
_____with more than one other person
_____playing games (cards, chess, etc.)
_____swimming
_____dancing
_____sleeping
_____watching TV

19. How well can you hear? ____poor;____fair;____average;____good;
____excellent.

20. Number of years as a college student:_____

21. Highest degree you have received:_____

22. Indicate the number of times you engate in the activities listed below in an average year.
_____one day outings (zoo, beach, etc.)
_____boating
_____overnight trips 5 days or less
_____overnight trips more than 5 days

22. (continued)

_____hiking
_____camping
_____visiting another major city
_____flying in a plane
_____riding in a train

23. How good is your sense of direction? ____poor;____fair; ____average;____good;____excellent.

24. How good is your ability to learn your away around a strange town or city? ____poor;____fair;____average;____good; ____excellent.

25. How good is your grasp of spatial relationships? ____poor; ____fair;____average;____good;____excellent.

26. Do you use a mobility aid such as a cane or guide dog? If so, what type and how often?

27. When and how did your vision become impaired?

28. Have you had formal mobility training?_____Explain:

29. How would you rate your overall physical independence?____poor; ____fair;____average;____good;____excellent.

30. Describe a typical day's activities. Include approximate times when possible.

EARLY EXPERIENCE QUESTIONNAIRE - PART II

To the parent or guardian:

Your son or daughter,_____, is participating in a research project involving several blind and sighted persons. The goal of the project is to gain knowledge which will aid in the design of better educational and training programs, especially those that con-ern the visually impaired.

This questionnaire is designed to provide information concerning the childhood experiences of your son or daughter. It should be completed by a parent or guardian with whom the person was reared. It is also important that all items are completed and that only a parent or guardian with whom the person was reared completes them. Each item should be answered as it applies to the above-name person. If additional space is required for any item, you may use the back of the page. Your cooperation in providing accurate information is greatly appreciated, since the results of this questionnaire will be used to design educational programs for blind and other handicapped children.

We request the name, address and phone number of the parent or guardian so that we may obtain additional information if the need arises. We guarantee confidentiality of all information. Again, please answer all items. Thank you for your help with this important project.

Dr. David H. Warren Terry L. Schmitt
Department of Psychology
University of California, Riverside

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31. Name of parent or guardian:_____

32. Address:_____

_____

33. Phone:_____

34. Was your child's birth natural?_____, or was medication used?_____

35. What was the birthweight of your child?_____lbs._____oz.

36. Was he/she in an incubator?_____ How long?_____

37. At what age was your child toilet trained when awake?_____mos.; when asleep?_____mos.

38. At what age did your child begin to communicate in phrases and short sentences?_____months

39. At what age did your child begin to crawl?_____months

40. At what age did your child begin to walk?_____months

41. List all occasions when the child was hospitalized during the first 16 years of life.

	age	length of stay	reason for stay
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

42. List any illnesses or conditions (for example, asthma, allergies, epilepsy, nervous or muscular disorders, etc.) which limited your child's physical activity.

illness or condition	age

43. Rate your child's health and estimate the number of days per year he/she was ill for each age period listed below. Include common illnesses.

age	overall health					no. days ill/year
0-2 years	poor	fair	average	good	excellent	
2-5 years	poor	fair	average	good	excellent	
5-10 years	poor	fair	average	good	excellent	
10-16 years	poor	fair	average	good	excellent	

44. List the number of adults (including yourself) and other children living in your immediate household during each of your child's first 16 years of life.

age(yrs.):	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
adults																
other children																

45. In the spaces below, give the information about each residence (in chronological order) in which you lived during the first 16 years of your child's life.

house(H) or apt.(A)	no. of rooms	miles from prev. res.	size of yard NONE,S,M,L	age of child	Pop. of community

46. Estimate the overall level of physical activity of your child for each of the age periods listed below. Use the following scale: 0 = not at all active; 1 = somewhat inactive; 2 = normally active; 3 = somewhat overactive; 4 = very active.

age:	0-6 mo.	6-mo.-1yr.	1-2yrs	2-5yrs	5-10yrs	10-16 yrs
compared to sighted children						
compared to other visually-impaired children						

47. For each age period, indicate the average number of hours the child slept each night: 0-2yrs____; 2-5yrs_____; 5-10yrs_____; 10-16yrs_____.

48. In an average week, how many hours was the father or male guardian at home for each age period?
0-2yrs_____; 2-5yrs_____; 5-10yrs_____; 10-16yrs_____.
How many hours was the mother or female guardian at home?
0-2yrs_____; 2-5yrs_____; 5-10yrs_____; 10-16yrs_____.

49. For each age period, estimate the number of hours in an average week the child spent in each activity category listed below. Some activities may contribute hours to more than one category. For example, time spent yardwork might also be included in time spent out-of-doors, time spent alone, etc.

	Age Periods			
Activities	0-2yrs	2-5yrs	5-10yrs	10-16yrs
playing alone	hr	hr	hr	hr
playing with other children	hr	hr	hr	hr
lying quietly or napping	hr	hr	hr	hr
playing with toys	hr	hr	hr	hr
yardwork	hr	hr	hr	hr
housework	hr	hr	hr	hr
climbing (trees, bars, etc.)	hr	hr	hr	hr
reading	hr	hr	hr	hr
drawing or painting	hr	hr	hr	hr

Activities	0-2yrs	2-5yrs	5-10yrs	10-16yrs
skilled work or play with hands (sewing, building models, etc.)	hr	hr	hr	hr
studying	hr	hr	hr	hr
in school or day-care facility	hr	hr	hr	hr
being cared for by someone other than you	hr	hr	hr	hr
indoors	hr	hr	hr	hr
out-of-doors	hr	hr	hr	hr
working with tools	hr	hr	hr	hr
organized sports	hr	hr	hr	hr
other organized activities (scouts, clubs, etc.)	hr	hr	hr	hr
playing a musical instrument	hr	hr	hr	hr
riding a tricycle or bicycle	hr	hr	hr	hr
watching TV	hr	hr	hr	hr
listening to radio or music	hr	hr	hr	hr
playing with mother	hr	hr	hr	hr
playing with father	hr	hr	hr	hr

50. For each of your child's age periods, estimate the number of times <u>per year</u> that he/she was included in each activity below.

Activity	0-2yrs	2-5yrs	5-10yrs	10-16yrs
went to park				
played on playground equipment				
child spent night away from home				
went to zoo, museum, etc.				
went hiking				
went to beach				

Activity	0-2yrs	2-5yrs	5-10yrs	10-16yrs
went to mountains				
other 1-day outings				
went boating				
went camping				
rode in an airplane				
overnight trips less than 5 days				
overnight trips more than 5 days				

51. For each of your child's age periods, estimate the economic level of your family.

Age	Economic level				
0-2yrs	lowest	low	middle	high	highest
2-5yrs	lowest	low	middle	high	highest
5-10yrs	lowest	low	middle	high	highest
10-16yrs	lowest	low	middle	high	highest

52. What is the highest educational level attained by the parent(s) or guardian(s)?

_____

_____

53. Estimate your child's physical independence. Consider whether or not he/she was always wandering off by himself as a child, was not afraid to explore new areas, provided own transportation (walking or otherwise), etc. Also consider your protectiveness of the child, i.e., did you always take him places when he might have walked; did you restrict him to room, house, or yard for fear of the child being hurt, etc.

0-2yrs:____not at all independent;____somewhat dependent; ____average;____somewhat independent;____very independent.

2-5yrs:____not at all independent;____somewhat dependent; ____average;____somewhat independent;____very independent.

53. (continued)

5-10yrs:____not at all independent;____somewhat dependent;
____average;____somewhat independent;____very independent.

10-16yrs:____not at all independent;____somewhat dependent;
____average;____somewhat independent;____very independent.

54. Describe when and how your child became visually impaired. Include the quality of any early vision your child may have had and the child's age at which vision was lost.

APPENDIX C: TABLE OF CORRELATIONS BETWEEN ALL DEPENDENT VARIABLES

The following table contains the correlations between all possible pairs of dependent variables measured in all tasks. The letters in parentheses following the dependent variable name specifies the task, complexity, and novelty conditions in which the variable was measured. Tactual pattern discrimination, tactual path learning and locomotor path tasks are specified by D, T and L, respectively. Simple and complex conditions are specified by S and C, respectively. Finally, familiar and novel conditions are specified by F and N, respectively. A single asterix (*) indicates a correlation with $p < .05$ and a double asterix (**) indicates a correlation with $p < .01$.

	1	2	3	4	5	6	7	8	9	10	11
1. d' (D,S)											
2. d' (D,C)	.46**										
3. β (D,S)	.56**	.09									
4. β (D,C)	.31*	.57**	.07								
5. Trials to Criterion(T,S)	-.56**	-.58**	-.19	-.26*							
6. Trials to Criterion(T,C)	-.39**	-.49**	-.14	-.08	.42**						
7. Overall Similarity(T,S)	.38**	.39**	.17	.20	-.63**	-.46**					
8. Overall Similarity (T,C)	.51**	.48**	.13	.27*	-.63**	-.52**	-.85**				
9. Final Similarity (T,S)	.37**	.35**	.22	.16	-.56**	-.42**	.92**	.77**			
10. Final Similarity (T,C)	.41**	.38**	.12	.20	-.55**	-.52**	.87**	.92**	.78**		
11. Overall Area (T,S)	-.46**	-.54**	-.23	-.24	.71**	-.33*	-.84**	-.73**	-.79**	-.72**	
12. Overall Area (T,C)	-.43**	-.54**	-.09	-.16	.49**	.69**	-.60**	-.67**	-.54**	-.68**	.51**
13. Final Area (T,S)	-.43**	-.35**	-.27*	-.18	.65**	.41**	-.86**	-.77**	-.87**	-.78**	.80**
14. Final Area (T,C)	-.36**	-.41**	-.18	-.13	.50**	.61**	-.75**	-.79**	-.70**	-.88**	.65**
15. Overall Distance (T,S)	.12	-.02	.05	-.08	.08	.09	-.57**	-.31*	-.52**	-.40**	.43**
16. Overall Distance (T,C)	.33*	.14	.07	.04	-.31*	.05	-.19	.03	-.12	-.16	-.07

	12	13	14	15	16	17	18	19	20	21	22
1. d' (D,S)											
2. d' (D,C)											
3. β (D,S)											
4. β (D,C)											
5. Trials to Criterion (T,S)											
6. Trials to Criterion (T,C)											
7. Overall Similarity (T,S)											
8. Overall Similarity (T,C)											
9. Final Similarity (T,S)											
10. Final Similarity (T,C)											
11. Overall Area (T,S)											
12. Overall Area (T,C)											
13. Final Area (T,S)	.54										
14. Final Area (T,C)	.73**	.64**									
15. Overall Distance (T,S)	.24	.41**	.33*								
16. Overall Distance (T,C)	.15	.12	.14	.57**							

	1	2	3	4	5	6	7	8	9	10	11
17. Final Distance (T,S)	.30*	.14	.02	.05	-.15	-.05	-.30*	-.03	-.32*	-.15	.12
18. Final Distance (T,C)	.14	.09	-.06	-.03	-.04	.05	-.38**	-.16	-.26*	-.33*	.12
19. Overall Abs. Dist. (T,S)	-.34*	-.40**	-.16	-.31*	.62**	.25*	-.81**	-.74**	-.77**	-.70**	.80**
20. Overall Abs. Dist. (T,C)	-.30*	-.33*	-.04	-.33*	.31*	.30*	-.68**	-.78**	-.64**	-.73**	.50**
21. Final Abs. Dist. (T,S)	-.29*	-.28*	-.09	-.24	.46**	.19	-.75**	-.75**	-.75**	-.69**	.62**
22. Final Abs. Dist. (T,C)	-.32*	-.28*	-.12	-.22	.42**	.37**	-.78**	-.84**	-.68**	-.85**	.60**
23. Similarity (L,S,F)	.38**	.40**	.07	.24	-.53**	-.35*	.77**	.77**	.76**	.78**	-.69**
24. Similarity (L,S,N)	.33*	.35**	.07	.18	-.36**	-.26*	.54**	.69**	.51**	.72**	-.50**
25. Similarity (L,C,F)	.40**	.42**	.04	.25	-.62**	-.38**	.69**	.75**	.66**	.70**	-.62**
26. Similarity (L,C,N)	.39**	.50**	.00	.23	-.61**	-.42**	.65**	.72**	.62**	.69**	-.57**
27. Area (L,S,F)	-.35*	-.41**	-.02	-.14	.53**	.31*	-.44**	-.46**	-.41**	-.45**	.52**
28. Area (L,S,N)	-.39**	-.36**	-.01	-.23	.44**	.41**	-.47**	-.50**	-.41**	-.53**	.49**
29. Area (L,C,F)	-.44**	-.33*	-.16	-.02	.36**	.39**	-.48**	-.55**	-.47**	-.56**	.55**
30. Area (L,C,N)	-.45**	-.38**	-.12	-.18	.56**	.19	-.38**	-.48**	-.38**	-.46**	.44**
31. Distance (L,S,F)	-.05	.13	.00	.01	.24	.01	.19	.14	.11	.01	-.13
32. Distance (L,S,N)	-.04	.04	-.01	.10	-.06	.12	.10	-.02	.07	-.12	-.09

	12	13	14	15	16	17	18	19	20	21	22
17. Final Distance (T,S)	.16	.31*	.12	.66**	.67**						
18. Final Distance (T,C)	.16	.28*	.30*	.59**	.83**	.64**					
19. Overall Abs. Dist. (T,S)	.45**	.82**	.53**	.39**	.08	.29*	.21				
20. Overall Abs. Dist. (T,C)	.43**	.61**	.59**	.35*	.23	.16	.37	.60**			
21. Final Abs. Dist. (T,S)	.31*	.73**	.49**	.33*	.02	.16	.11	.84**	.69**		
22. Final Abs. Dist. (T.C)	.54**	.71**	.71**	.40**	.34*	.18	.43	.67**	.81**	.68**	
23. Similarity (L,S,F)	.56**	-.70**	-.63**	-.30*	-.02	-.06	-.10	-.65**	-.60**	-.67**	-.71**
24. Similarity (L,S,N)	.57**	-.47**	-.65**	-.20	-.02	.02	-.11	-.44**	-.53**	-.47**	-.57**
25. Similarity (L,C,F)	-.57**	-.71**	-.61**	-.32**	.02	-.06	-.09	-.61**	-.47**	-.58**	-.63**
26. Similarity (L,C,N)	-.62**	-.63**	-.68**	-.15	.04	-.01	-.11	-.52**	-.50**	-.54**	-.60**
27. Area (L,S,F)	.32*	.35**	.40**	.02	-.28*	-.30*	-.19	.36**	.36**	.30**	.32**
28. Area (L,S,N)	.55**	.46**	.53**	.14	.03	.04	.12	.41**	.32**	.33*	.39*
29. Area (L,C,F)	.65**	.46**	.59**	.14	-.09	-.02	.00	.35**	.31*	.23	.42**
30. Area (L,C,N)	.38**	.32*	.43**	-.09	-.32*	-.31*	-.10	.28*	.19	.29*	.29*
31. Distance (L,S,F)	-.02	-.28	.13*	.00	-.16	-.21	-.10	-.44**	-.01	-.35**	-.22
32. Distance (L,S,N)	.10	-.23	.29*	.05	-.13	-.14	.04	-.39**	.04	-.27*	-.11

	23	24	25	26	27	28	29	30	31	32	33
17. Final Distance (T,S)											
18. Firal Distance (T,C)											
19. Overall Abs. Dist. (T,S)											
20. Overall Abs. Dist. (T,C)											
21. Final Abs. Dist. (T,S)											
22. Final Abs. Dist. (T,C)											
23. Similarity (L,S,F)											
24. Similarity (L,S,N)	.80**										
25. Similarity (L,C,F)	.72**	.69**									
26. Similarity (L,C,N)	.75**	.76**	.86**								
27. Area (L,S,F)	-.58**	-.50**	-.57**	-.56**							
28. Area (L,S,N)	-.68**	-.72**	-.63**	-.68**	.48**						
29. Area (L,C,F)	.62**	-.68**	-.72**	-.68**	.54**	.63**					
30. Area (L,C,N)	-.63**	-.72**	-.59**	-.72**	.58**	.63**	.58**				
31. Distance (L,S,F)	.12	-.05	.29*	.24	.04	-.02	.05	-.01			
32. Distance (L,S,N)	.07	-.19	.05	.00	.18	.02	.16	.20	.76**		

	1	2	3	4	5	6	7	8	9	10	11
33. Distance (L,C,F)	.19	.06	.04	.11	-.25*	-.09	.40**	.48**	.45**	.34*	-.36**
34. Distance (L,C,N)	-.17	-.10	-.05	.00	.12	.18	-.01	-.11	-.08	-.19	.15
35. Absolute Distance (L,S,F)	-.32*	-.44**	-.08	-.19	.54**	.27*	-.68**	-.63**	-.74**	-.58**	.69**
36. Absolute Distance (L,S,N)	-.34*	-.34*	-.12	-.22	.34*	.24	-.51**	-.61**	-.50**	-.65**	.59**
37. Absolute Distance (L,C,F)	-.37**	-.23	-.10	-.07	.43**	.22	-.45**	-.41**	-.53**	-.42**	.42**
38. Absolute Distance (L,C,N)	-.18	-.29*	-.07	-.13	.36*	.19	-.50**	-.58**	-.56**	-.60**	.57**
39. Starting Point (L,S,F)	-.36**	-.26**	-.02	-.11	.32*	.20	-.32*	-.40**	-.32*	-.41**	.28*
40. Starting Point (L,S,N)	-.38**	-.43**	-.06	-.21	.52**	.29*	-.46**	-.48**	-.49**	-.49**	.61**
41. Starting Point (L,C,F)	-.21	-.28**	-.09	-.10	.40**	.21	-.40**	-.21	-.37**	-.28*	.52**
42. Starting Point (L,C,N)	-.30*	-.36**	-.06	-.25	.34*	.30*	-.57**	-.55**	-.49**	-.62**	.59**

	12	13	14	15	16	17	18	19	20	21	22
33. Distance (L,C,F)	-.34*	-.37**	-.19	-.19	-.08	-.06	.13	-.51**	-.20	-.46**	-.41**
34. Distance (L,C,N)	.15	-.03	.27*	.01	-.31*	-.27*	-.23	-.22	.04	-.15	-.01
35. Absolute Distance (L,S,F)	.44**	.59**	.52**	.32*	-.09	.06	-.07	.67**	.42**	.67**	.50**
36. Absolute Distance (L,S,N)	.49**	.39**	.61**	.31*	.02	.01	.08	.47**	.41**	.47**	.55**
37. Absolute Distance (L,C,F)	.31*	.58**	.39**	.19	-.15	.07	-.01	.45**	.32*	.51**	.37**
38. Absolute Distance (L,C,N)	.44*	.38**	.59**	.25	-.10	-.03	.03	.46**	.49**	.43**	.46**
39. Starting Point (L,S,F,)	.34*	.22	.34*	-.01	-.09	-.06	-.10	.25*	.18	.22	.29*
40. Starting Point (L,S,N)	.41**	.62**	.44**	.21	.01	.17	.13	.48**	.21	.27*	.33
41. Starting Point (L,C,F)	.12	.39**	.22	.33*	.00	-.02	.01	.30*	.06	.16	.18
42. Starting Point (L,C,N)	.40**	.56**	.52**	.33**	.19	.30*	.25	.56**	.34*	.39**	.41**

	23	24	25	26	27	28	29	30	31	32	33
33. Distance (L,C,F)	.44**	.29*	.50*	.32*	-.15	-.28*	-.32*	-.26*	.39**	.32*	
34. Distance (L,C,N)	-.22	-.34*	-.01	-.04	.28*	.18	.25*	.32	.67**	.67**	.16
35. Absolute Distance (L,S,F)	-.73**	-.61**	-.74**	-.71**	.65**	.57**	.52**	.61**	-.31*	-.15	-.59**
36. Absolute Distance (L,S,N)	.68**	-.82**	-.65**	-.65**	-.55**	.72**	.66**	.63**	.01	.18	-.42
37. Absolute Distance (L,C,F)	-.44**	-.47**	-.76**	-.68	.38**	.42**	.52**	.44**	-.21	-.06	-.33*
38. Absolute Distance (L,C,N)	-.58**	-.66**	-.55**	-.59**	.62**	.59**	.54**	.57**	.23	.31*	-.40**
39. Starting Point (L,S,F)	-.66**	-.67**	-.44**	-.50**	.39**	.58**	.47**	.63**	-.04	.02	-.17
40. Starting Point (L,S,N)	-.57**	-.54**	-.63**	-.62**	.34*	.65**	.53**	.49**	-.14	-.08	-.21
41. Starting Point (L,C,F)	-.39**	-.12	-.36**	-.20	.45**	.17	.30*	.23	.00	-.04	.00
42. Starting Point (L,C,N)	-.50**	-.45**	-.54**	-.49**	.31*	.46**	.42**	.29*	-.17	-.05	-.25*

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	34	35	36	37	38	39	40	41	42
33. Distance (L,C,F)									
34. Distance (L,C,N)									
35. Absolute Distance (L,S,F)	.03								
36. Absolute Distance (L,S,N)	.30*	.71**							
37. Absolute Distance (L,C,F)	-.01	.58**	.46**						
38. Absolute Distance (L,C,N)	.36**	.65**	.74**	.46**					
39. Starting Point (L,S,F)	.19	.46**	.49**	.19	.27*				
40. Starting Point (L,S,N)	.04	.46**	.14	.45**	.36**	.55**			
41. Starting Point (L,C,F)	.01	.33*	.49**	.15	.08	.35**	.50**		
42. Starting Point (L,C,N)	-.12	.46**	.45**	.21	.33*	.42**	.71**	.44**	

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